ÓL. XIX — N° 7 JULY 1937

Monthly Bulletin of the International Railway Congress Association

(English Edition)

PRINTED IN BELGIUM

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MONTHLY BULLETIN

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

(ENGLISH EDITION)

PUBLISHING and EDITORIAL OFFICES: 231, RUE ROYALE, BRUSSELS.

Yearly prepaid subscription { **Belgium . . . . . 70 Belgas** / **Other countries . . 75 Belgas** } including postage

Price of this single copy: 8 Belgas (not including postage).

(1 Belga = 5 Belgian francs.)

Subscriptions and orders for single copies (January 1931 and later editions) to be addressed to the General Secretary, International Railway Congress Association, 231, rue Royale, Brussels (Belgium).

Orders for copies previous to January 1931 should be addressed to Messrs. Weissenbruch & Co. Ltd., Printers, 49, rue du Poinçon, Brussels.

Advertisements: All communications should be addressed to the Association, **231, rue Royale, Brussels.**

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BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[656]

Competition by roads, waterways and airways.

(Continuation) (1).

Great Britain.

By courtesy of the British Railway Clearing House, we publish hereafter a memorandum of the British Railway Companies showing developments in regard to competition and co-ordination between road and rail during the year 1936.

Legislation.

Road Traffic Act, 1930.

There have been no material alterations or amplifications of the above Act during the year 1936.

The decrease in the number of small operators, mainly due to absorptions by larger companies, as referred to in the Report for the year 1935, has been continued as is shewn by the following figures :

At 31st December.	Number of operators owning :			Total number of vehicles owned by :		
	Up to 49 vehicles. (1)	50 or more vehicles. (2)	Total. (3)	(1)	(2)	(3)
1933	5 814	112	5 926	18 329	27 064	45 393
1934	5 620	115	5 735	17 713	28 082	45 795
1935	5 186	114	5 300	16 976	29 461	46 437

Appeals.

The Minister of Transport has decided that the conditions attached to certain road service licences be varied so as to provide that the age below which children shall be carried free of charge shall be three years.

This ruling is made in respect of the particular licences under appeal but the tendency now is for the decision to be made generally applicable and so standardise the practice throughout the country which hitherto has varied between 3 to 6 years.

(1) See *Bulletin*, June 1934 to June 1936.

Road and Rail Traffic Act, 1933.

There have been no alterations or amplifications of this Act during the year 1936.

With regard to the number of vehicles on the roads a comparison of the position at 30th September, 1935, as published in the first Annual Report of the Licensing Authorities, with the position at 30th April, 1936, as published in the Ministry of Transport Statistics, gives the following results :

	Licences.		(*) Vehicles authorised.		Average number of vehicles per licence.	
	1935	1936	1935	1936	1935	1936
(**) A Licences	28 739	28 916	100 182	102 855	3.49	3.55
(**) B Licences	35 279	34 320	55 558	54 590	1.57	1.59
(**) C Licences	149 282	161 535	303 886	329 195	2.04	2.03
Total.	213 300	224 771	459 626	486 640	2.10	2.16

From the foregoing particulars the following facts are to be observed :

The number of « A » licensed vehicles has increased by 2 673.

The number of « B » licensed vehicles has decreased by 968.

There has been a formidable increase viz., 25 309, in the number of « C » licensed vehicles.

The net increase of vehicles is 27 014.

The proportion of « C » licensed vehicles (April, 1936) to the total number of vehicles was 67 per cent.

Included in these figures (April 1936) are 9 045 vehicles and 3 549 trailers on « A » licences and 78 vehicles on « C » licences owned by the Railway Companies.

Of the operators holding « B » licences, 40 % were coal merchants, colliery proprietors, etc.; 8 % were in the building line; 6 % were farmers, dairymen or livestock dealers; 6 % were greengrocers or fruiterers.

Of the « B » licences granted, 40 % were restricted to a radius of 20 miles or less; 30 % were limited to a radius exceeding 20 miles but not exceeding 50 miles.

Notes.

(*) Including trailers, which are licensed as separate units.

(**) The different classes of licenses for goods vehicles are as under :

« A » licences. — Public Carriers — Licence valid for two years.

« B » licences. — Persons who carry goods in connection with any trade or business of their own and also as public carriers. These licences which are valid for one year may have attached to them conditions limiting conveyance for hire or reward to :

(a) A defined area or between specified places.

(b) Certain classes of goods only.

(c) Goods of specified persons.

« C » licences. — Persons who carry goods in connection with their business only — Licences valid for three years.

Appeals.

The following important principles have been laid down by the Appeal Tribunal during the course of the year :

(*a*) If suitable facilities are, or would be, in excess of requirements, then generally speaking an application by an existing « A » licensed operator to increase his fleet should not be granted. The term « suitable » is to be interpreted as meaning more than « adequate » and the requirements must be considered in relation to current industrial and commercial conditions as well as those of the applicant and objector.

(*b*) A manufacturing company using a fleet of vehicles to deliver their products and who had in the past held a « B » licence and made a practice of carrying goods for hire or reward on the return journey, applied for renewal of the licence at the termination of the currency period. It was decided by the Licensing Authority and upheld by the Appeal Tribunal that the carrying of return loads for hire or reward in such circumstances is not generally in the public interest provided alternative transport is available and there are no special circumstances attaching to the application.

(*c*) It was held by the Appeal Tribunal that a coal merchant who hawked coal during the winter months should be granted a « B » licence even though he is unable to discharge the ordinary burden of proof required to justify carrying for hire or reward provided : *(a)* his bussiness as a coal merchant is genuine; *(b)* a vehicle is necessary and his own goods cannot be carried satisfactorily otherwise; (*c*) the vehicle cannot be economically operated unless used during the off season for hire and reward; and provided special conditions be attached to the licence preventing carrying for hire except during the off season and preventing wasteful competition. This principle does not necessarily apply to other seasonal bussinesses.

(*d*) In refusing an application by a road operator for additional tonnage on trunk services, the Licensing Authority stated : « The mere reason that delivery by road was quicker than by rail was not in itself sufficient to indicate that the rail facilities were unsuitable and therefore the carriage of that traffic (new business to the road operator) was wastefully competing with the railways ». This decision was upheld by the Appeal Tribunal.

Regulation of road transport wages.

The Ministers of Labour and Transport of the British Government have constituted a Committee to consider the question of the regulation of wages in the road transport industry (goods).

The terms of reference to this Committee are to examine the present position in regard to the regulation of wages and conditions of service of persons employed in connection with the carriage of goods by road (whether in vehicles authorised under « A », « B » or « C » licences), and to make recommendations as to the action which it is desirable to take.

The work of this Committee is proceeding but their Report is not yet available.

New legislation.

Trunk Roads Act, 1936.

An Act was passed by the British Parliament in December 1936, under which provision is made for the transfer from the local highway authorities to the Minister of Transport of the liability for

the maintenance, repair and improvement of approximately 4 500 miles of existing trunk roads in Great Britain, which constitute the national system of principal routes for through traffic, and for making consequential amendments in the law relating to highways.

Measures taken by the railways themselves to combat road competition.

Passenger and goods traffic.

Electrification.

Further extensions have been made in the electrification of the British Main Line Railways during the past two years, and the total mileage at the end of 1936 was 1 584 electrified track miles. This mileage does not include services solely operated by the London Passenger Transport Board.

Agreed charges.

The Road and Rail Traffic Act of 1933 empowered the British Railway Companies to enter into agreements, with the sanction of the Railway Rates Tribunal, for the conveyance of merchandise at agreed charges. (Reference to this arrangement was made in the Report for the year 1934 (1). In the first instance, the traders themselves took the initiative in asking for an « agreed charge » to be made. At the present moment, however, the Railway Companies are bringing these facilities to the notice of large traders as it is found that the saving in clerical labour is appreciated by the traders, and it has helped the Railway Companies to regain a certain amount of traffic from the road.

At the end of 1936 there were 367 agreed charges in operation approved by the Railway Rates Tribunal as compared with 200 at December, 1935.

In addition, at the end of 1936, 168 agreed charge offers had been accepted by Traders and were awaiting the approval of the Tribunal.

The agreed charges in operation at June, 1936, altogether accounted for 2 1/2 % of the total revenue of parcels and goods train traffic.

Goods traffic.

Partitioning in covered vans.

Experiments have been conducted with partitions in covered goods vans as a development associated with the prevention of damage to goods in transit. The partitioning of the truck space was arranged by means of moveable boards inserted into slots fitted to the interior sides of the vehicles (apart from the space opposite the doors) at intervals of six inches.

The partitions consist of six boards constructed in such a way that there is left a space between them for easy handling, and when not required to support traffic in the van are nested at the end of the truck.

In this way it is possible to divide the interior of the truck as required, but at the same time to conform to loading requirements. The support thus given to damageable commodities such as eggs, soft fruit. furniture, etc., traffics which, however carefully handled, are in themselves inevitably susceptible to damage, has proved an important factor in counteracting much of the shock and displacement sometimes occasioned by transit oscillation, the starting and stopping of trains and the shunting of the trucks.

After exhaustive tests covering some hundreds of journeys, it has been established that the greater security afforded by the use of the partitions ensures equally greater immunity from transit damage.

(1) *Bulletin of the Railway Congress*, May 1935, p. 485.

Additions to the British Railways' stock of freight vehicles fitted with the vacuum brake.

The following particulars indicate the increase in the numbers of brake-fitted vehicles, excluding mineral wagons and brake vans, for the years 1931 to 1935 inclusive :

Number of brake-fitted freight vehicles (excluding mineral wagons and brake vans).					Percentage 1935 over 1931.
1931	1932	1933	1934	1935	
46 221	49 827	53 548	60 253	71 865	55 %

[621. 43 (43)]

Fast railcars of the German State Railways,

by Reichsbahndirektor STROEBE,
Railway Department of the German Min stry of Transport.

More than three years have elapsed since, for the first time in the history of railways, the German State Railways (Reichsbahn) opened a daily service with fast railcars which were to run at speeds of 150 km. (93 miles) per hour and over. When on May 15th, 1933, the first fast railcar was put into service on the Berlin-Hamburg line, technical circles and the public showed a keen interest in this initiative. On the other hand, this fast service was such an innovation and was so different from all what existed at that time, that serious objections of a technical or practical nature were raised in various quarters. Nonetheless, a short time after the fast railcar (Schnelltriebwagen) was put into service, the particular features of this new form of transport prompted the other countries in Europe and other parts of the World to investigate the organisation of similar services. The « Flying Hamburger » became the prototype of the fast modern rail vehicle (fig. 1).

As, on the other hand, fast services have been markedly extended on the German main lines, and the number of high-speed railcars has grown from year to year, it is now possible to give some information on the results obtained with these vehicles in service. In connection with this, we will first of all recall the chief constructional features of the « Flying Hamburger », which was, moreover, described in a detailed manner in the technical press.

* * *

This fast railcar includes two bodies resting on an intermediate (common) bogie, of the so-called Jakobs type. Its overall length is 42 m. (137′ 9″); it is carried on three four-wheeled bogies, the distance between bogie centers being about 17 m. (55′ 9″), and its weight (empty) is about 74.5 t. (73.3 Engl. tons). The body framing is of steel, the side walls performing load-carrying functions. Welding has been resorted to on a large scale for assembling the various parts, which made it possible to keep the total vehicle weight at a relatively moderate figure, avoiding at the same time the use of light construction properly speaking, for reasons of safety in case of accident.

The railcar has two large passenger compartments providing 102 seats together, as well as a luggage compartment and a small bar room in which passengers can be supplied with drinks or light meals. Each coach body has its own hot water heating installation, with a special boiler (fig. 2).

Owing to the high speed at which the vehicle has to run, the air resistance is a far more important factor than all the other resistances to motion. Thus, the

Fig. 1. — Fast diesel-electric railcar, the « Flying Hamburger ». Built in 1932.

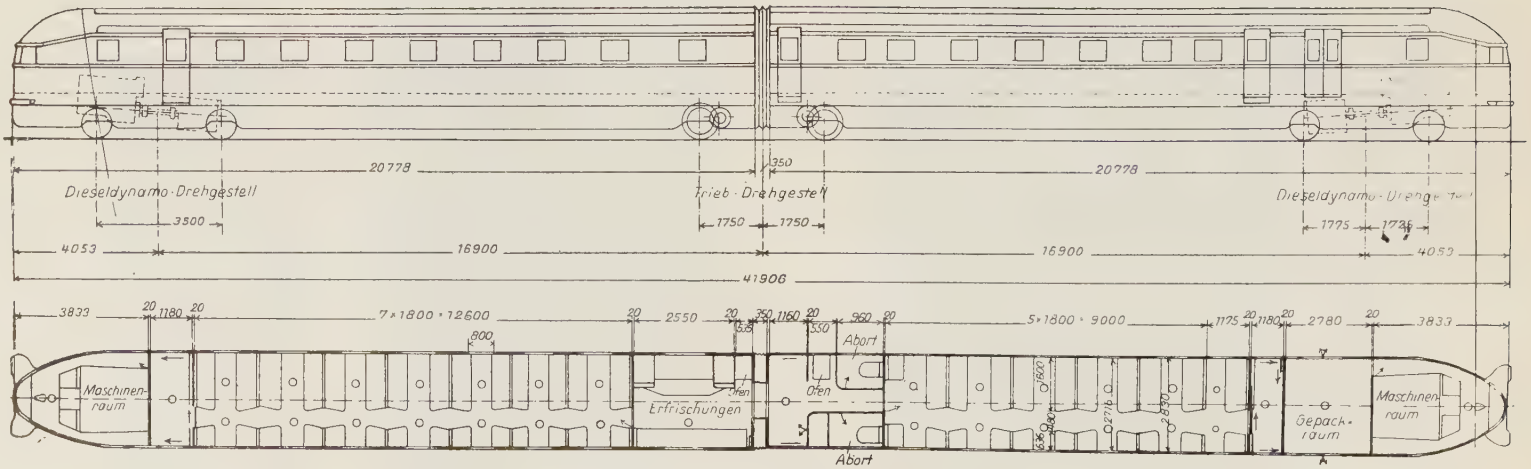


Fig. 2. — Elevation and plan of the « Flying Hamburger ».

Note. — Dieseldynamo-Drehgestell = bogie carrying a diesel-generator set. — Trieb-Drehgestell = motor bogie. — Maschinenraum = engine room. — Erfrischungen = bar. — Abort = w.c. — Ofen = stove. — Gepäckraum = luggage compartment.

problem before the designers consisted in reducing the air resistance as much as possible, by giving the railcar body an appropriate shape. It was found necessary to innovate in this connection, because the « drop » form adopted for high-speed vehicles used in road, water and air transport could not be employed, in spite of its good aerodynamic properties.

The railway service requires a vehicle which can be readily driven in both directions. Consequently, both vehicle ends had to have the same shape, i.e. a compromise had to be found, in practice, between the theoretically best shape for the front end and that for the rear end. Extensive tests carried out on small models in the wind flume of the Zeppelin Aircraft Works, at Friedrichshafen (Lake of Constance) resulted in a shape, which, in view of the state of knowledge at that time, could be said to be exceptionally successful (fig. 3).

But it was not only to the perfect shape of the vehicle ends that very great attention was given; the side walls were, as far as possible, free from all projections, and in order to avoid eddies near the ground, they were fitted with plate aprons extending low down. The results obtained with the model in the wind flume were checked later on by means of road tests and taken advantage of when designing new vehicles.

The motive power equipment included two generating sets, each with a 410-H.P. diesel engine, with electric transmission. Each generator, coupled to its diesel engine, was mounted in one of the outer bogies (fig. 4), whereas the two electric traction motors were housed in the intermediate Jakobs bogie (fig. 5). The diesel engines used, of the 12-cylinder high-speed Maybach type, have since been adopted by many Administrations and proved themselves everywhere. At the time of this application, special importance had been attached to their low weight and the little space they took up, which allowed of engines of such a power to be carried in the bogies. Besides, this arrangement has subsequently given such satisfactory results that the Reichsbahn is still preferring it.

In order to simplify the control of the

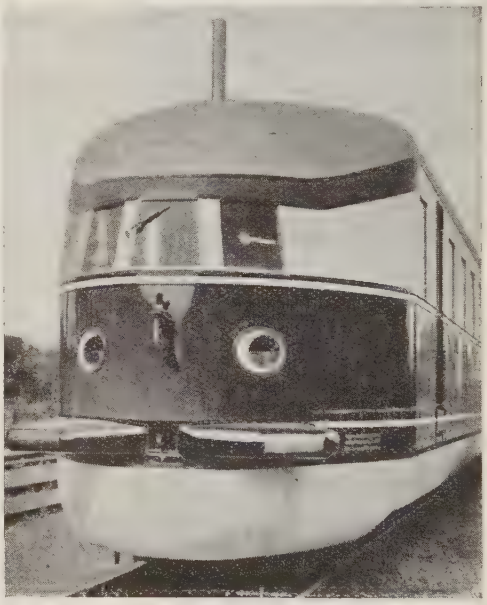


Fig. 3. — Front end of the « Flying Hamburger ».

vehicle as much as possible, as the driver's full attention is required for observing the road and the signals, the « Gebus » system of transmission had been adopted. This system includes a self-exciting shunt-wound generator, permanently electrically coupled to the traction motors. The power developed is automatically regulated by the number of revolutions p.m. of the diesel engine. The

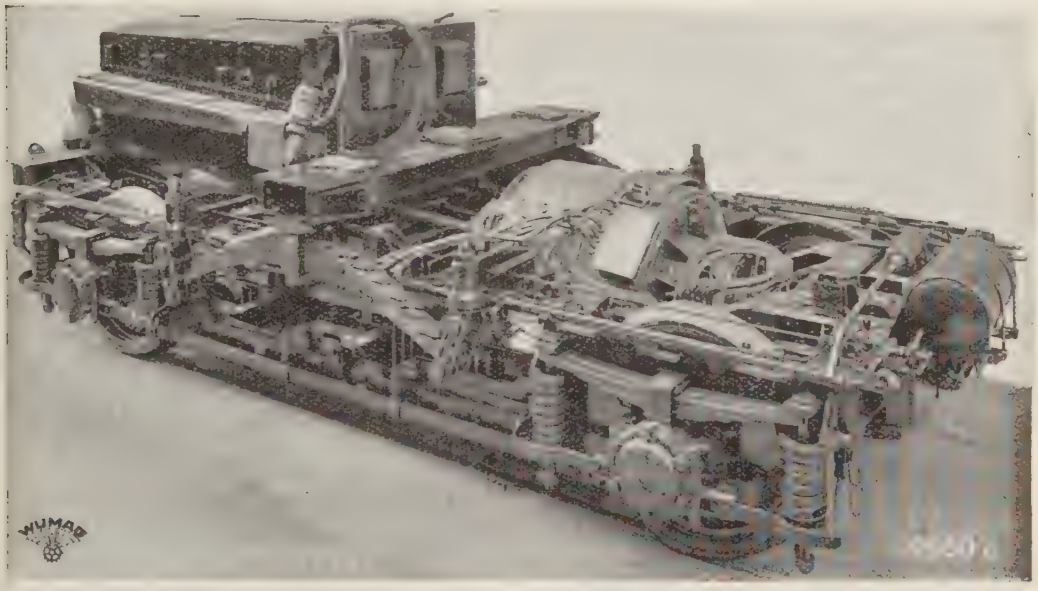


Fig. 4. — Motor bogie of the « Flying Hamburger ».

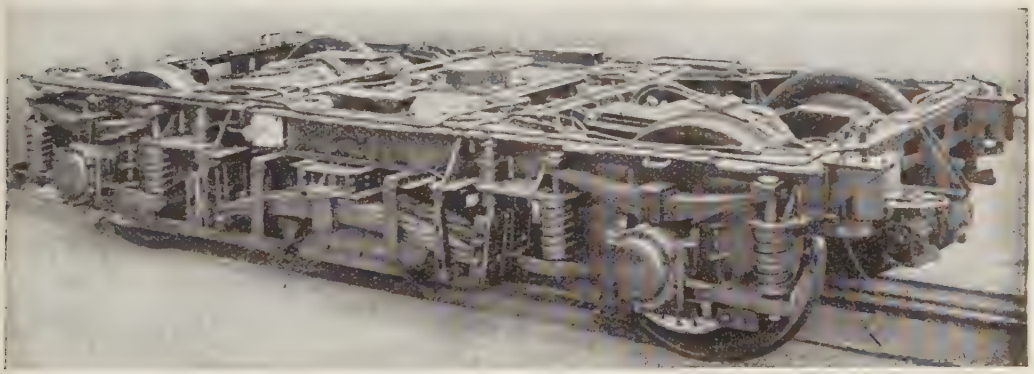


Fig. 5. — Jakobs bogie carrying the traction motors, of the « Flying Hamburger ».

generator works under low magnetic saturation. When, owing to the required tractive effort increasing, the current intensity grows, the voltage of the generator decreases in a sufficient proportion for the diesel engine not having to develop a power higher than that corresponding to the desired number of r.p.m. Only within a very small range is the diesel engine somewhat overloaded, which is reflected in a slight reduction of its number of r.p.m. However, when

the exciter rheostats are well adjusted, this reduction remains within quite acceptable limits.

A certain drawback of this system of transmission is the relatively slow increase of the starting current after switching on. The reason is that the purely self-exciting generator has first of all to build up its magnetic field. However, such drawback has no importance in the case of a fast railcar making long non-stop runs, and which consequently does not make frequent starts.

In order that the railcar might be stopped with certainty from its high running speeds, within the prescribed distance between the distant signal and the home signal, which distance was increased to 1 200 m. (3936′) in the case of high-speed services on the Berlin-Hamburg line, special care was devoted to the brake equipment. The railcar was equipped with a new system of drum brake, using a new lining of artificial material; the frictional force developed by such linings is well adapted to the corresponding value of the adhesion between wheel and rail, so that the braking is completed without difficulty and without jolts within the prescribed stopping distance. The railcar was also equipped with an electro-magnetic rail brake, to be used as an emergency brake. As this brake does not act upon the wheels, but on the rails, it has been possible to calculate its power independtly from the adhesion. In case of emergency, the railcar, when running at its maximum speed of 160 km. (100 miles) an hour, can be stopped, under the conjugated action of the two brakes, within a distance of 800 m. (2 624′).

Two other safety measures consisted in equipping the vehicle with the « dead man's handle », and the automatic train control system of the inductive type, by which, for example, if the railcar were to pass a signal at « danger », an emergency application of the brakes would be effected.

Obviously, with this vehicle of an entirely new type as regards many details, still many other difficulties had to be overcome at the beginning, as in the case of a number of important constructional parts mentioned above, new ground had been broken. Let us further recall that at high speeds the « Flying Hamburger » showed quite perceptible oscillations along the centre line of the track, which exerted an unfavourable effect on the riding of the vehicle. This phenomenon had not been noticed within the speed ranges usually practised up to then with railway vehicles. After a close investigation of the problem and many test runs, it became possible to completely overcome this difficulty. The necessary runs in this connction could not, of course, be effected while the vehicle was in regular service, but special runs had to be resorted to, during which the railcar was not available for ordinary traffic purposes.

The timings of the « Flying Hamburger » were drawn up for a speed of 150 km. (93 miles) an hour, which speed could be increased to 160 km. (100 miles), for making good lost time. Taking into account the fact that the « Flying Hamburger » had to run at reduced speed when leaving Berlin and entering Hamburg station, this railcar reached an overall (commercial) speed of 125.6 km. (78.1 miles) an hour, covering the 287-km. (178.3 miles) run in 137 minutes. It was, in fact, the fastest passenger train in the World.

Figure 6 shows the distance (in kilometres) covered monthly by the « Flying Hamburger » between May 15th, 1933,

and June 30th, 1935; at the latter date, the vehicle was taken out of service and sent to the Nuremberg Railway Centenary Exhibition. The second curve of the same figure shows the *factor of use*, i.e. the ratio of the specified performance to that really effected during the different months. It definitely shows how, at the beginning, the vehicle was more often out of service for tests, and for maintenance or improvement work. However, if the result is considered as a whole in respect

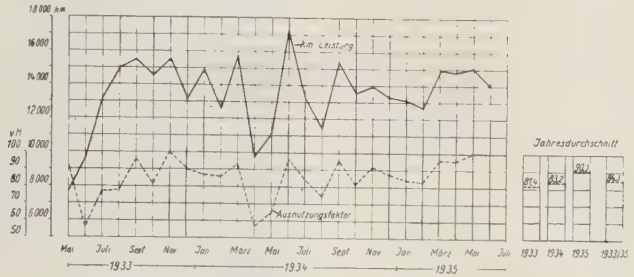


Fig. 6. — Distance (in km.) covered by, and factor of use of, the « Flying Hamburger ».

Note. — Km.-Leistung = distance covered in km. — Ausnutzungsfaktor = factor of use. — Jahresdurchschnitt = yearly average.

of the 26 months of service on the line, the impression is quite a favourable one. During this period, the railcar covered, in round figures, 352 000 km. (218 700 miles), i.e. 540 km. (335 miles) per day on the average, excluding Sundays and holidays, the railcar not being run on such days. An idea of the meaning of these figures can be gathered from the fact that, during the said period, the vehicle would have run 9 times round the Equator. The average factor of use for the whole period reaches 84 %. Consequently there remains only 16 % for the tests and maintenance work.

Figure 7 shows the consumption of

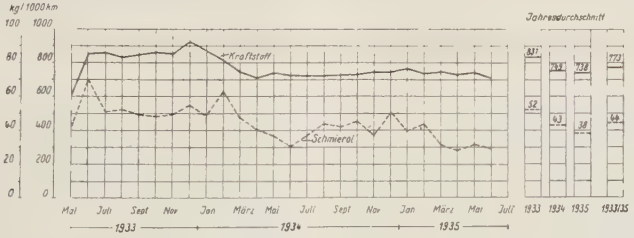


Fig. 7. — Fuel and lubricant consumption of the « Flying Hamburger ».

fuel oil and lubricants per 1 000 km. run during the 26 first months. The curves clearly show the progressive effect of the improvements effected in the engines. From 831 kgr. per 1 000 km. for two engines in 1933, the fuel consumption fell to 749 kgr. in 1934 and 738 kgr. per 1 000 km. in 1935. The lubricating oil consumption followed a similar curve — 1933 : 52 kgr.; 1934 : 43 kgr., 1935 :

38 kgr. per 1 000 km. These figures are directly comparable, as the railcar has always been in service on the same line.

As regards *repair costs,* no accurate information can be supplied for the same period, as the total expenditure not only includes maintenance costs, but also those incurred in respect of tests and improvements. According to the findings of recent enquiries, it may be said that all expenses, including interest, amortization, improvements, etc., are largely made good by the receipts. This result has been obtained because, from the beginning, the fast railcar found much favour with the public. Particularly, foreigners arriving at Hamburg by boat showed a marked predilection for this vehicle, as the « Flying Hamburger » had become a type of train known all the World over.

Since then, the railcar has covered over 420 000 km. (261 000 miles). Its factor of use invariably remains between 85 % and 90 %. After a general and very careful overhaul, its average consumption figures are now 655 kgr. per 1 000 km. (2 323 lb. per 1 000 miles) in respect of fuel oil, and 30 kgr. per 1 000 km. (106.4 lb. per 1 000 miles) as regards lubricating oil.

These favourable results induced the Reichsbahn to extend its fast railcar services. As early as 1934, the « Maschinenfabrik Görlitz » (Wumag), who built the first vehicle of that kind, was given *an*

Fig. 8. — Fast diesel-electric railcar built in 1934.

order for 13 other railcars (fig. 8). If this new stock is similar, in its essential features, to its prototype, the growing requirements and modern traffic conditions have led to remarkable constructional and mechanical improvements being effected in the case of these vehicles. The new fast railcars first of all differ from the first one by the more favourable streamlined shape adopted for their ends, following the results of recent research work. This shape allows of better proportioning the driver's compartment, and at the same time gives the railcar a pleasing aspect (fig. 9). The rubber buffers which constituted one of the main features of the « Flying Hamburger » are no longer used on the new vehicles, a Scharfenberg central automatic coupling being used, by means of which several fast railcars can be coupled together. In order to avoid as far as possible air eddies being set up under the railcar, the lateral aprons have been ex-

Fig. 9. — Front end of fast diesel-electric railcar built in 1934.

tended underneath the body, so as to form a shrouding for the bottom of the car.

The rounding off of all edges has received particular attention. The side apron can be tipped up throughout its entire length in order to give easy access to all the parts encased in it. In order to enlarge the luggage and passenger compartments, the new twin railcars were made over 2 m. (6′ 6 3/4″) longer, and the resistance to impact of the body has been increased by strengthening the underframe and the ends. On the other hand, the adoption of a central coupling has also made it necessary to markedly alter and strengthen the vehicle ends. The double windows, which are particularly wide, give a much better view from inside the vehicle, which is appreciated by the passengers. In order to retain sufficient strength to the side walls, in spite of the presence of these

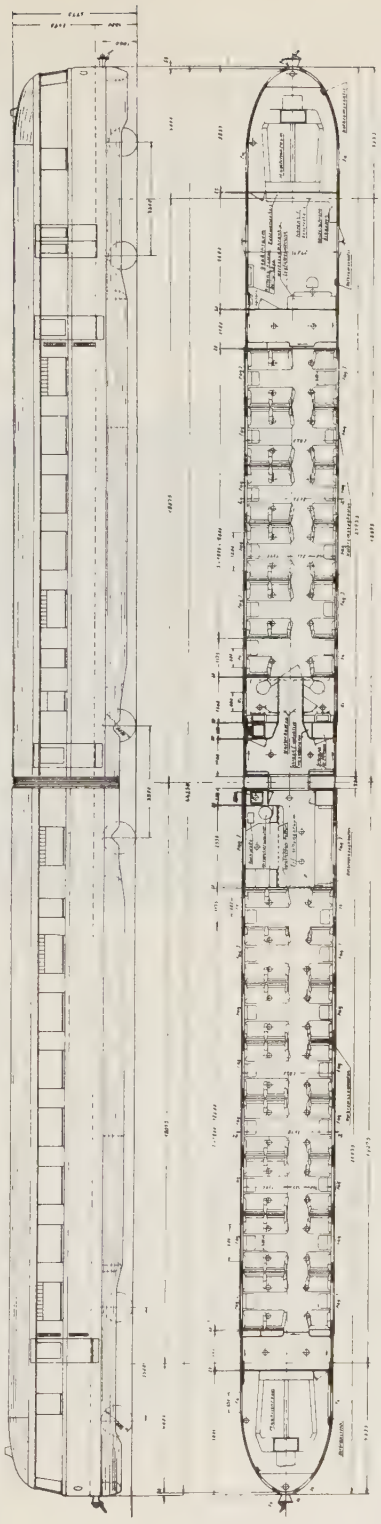


Fig. 10. — Elevation and plan of fast diesel-electric railcar built in 1934.

Voir, Maschinenraum = engine room. — Notbremsventil = emergency brake valve. — Ölkännen = oil cans. — Wasserkasten = water tank. — Leitern = ladders. — Rettungskasten, Beil und Säge = First aid chest, axe and saw. — Werkzeugschrank = tool chest. — Zug-führerschrank = guard's cupboard.

wide windows, the former had to be specially stiffened.

The interior lay-out and fitting-out of the new railcars generally remained the same (fig. 10). However, whereas there were formerly 8 seats per compartment, the new vehicles only provide 6 particularly comfortable upholstered seats, with removable cushions (fig. 11). The new railcars provide a total of 77 seats. The 4 seats in the bar room have been done away with, and the recovered space has been placed at the disposal of the *Mitropa,* in order to enlarge the pantry, owing to the large amount of work required from the kitchen, which is kept quite busy by the passengers. Another improvement is the continuous ventilat-

Fig. 11. — Inside view of fast railcar built in 1934.

ing duct provided in the roof. The lighting of the large passenger compartments has been increased. As formerly, the heating is by circulated hot water.

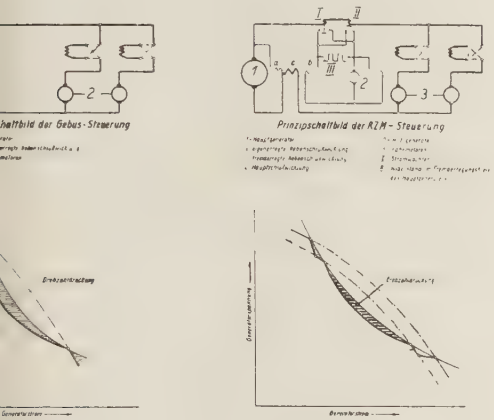
The general arrangement of the diesel equipment, consisting as formerly of two 410-H.P. Maybach engines carried in the bogies, has only been slightly altered. The cooling plant has been improved, and all auxiliary apparatus and the piping arranged so as to facilitate their inspection and access.

A particular feature is that the diesel engine and its generator are freely suspended in the bogie; this arrangement, which had been successfully tried on the « Flying Hamburger » not only improves the riding of the vehicle, but also preserves the mechanical equipment.

The electrical equipment was built, following the same design, by the « Allgemeine Elektrizitäts-Gesellschaft » (A.E.G.) and the « Siemens-Schuckert Werke ». Whereas the first fast railcar was fitted with a Gebus transmission, the new railcars are equipped with a new transmission designed by the « Reichsbahn-Zentralamt fur Maschinenbau »

(R.Z.M. transmission), which uses a combined excitation for the generator, instead of the self-excitation of the Gebus system.

For equal diesel engine speeds by the combined use of separate excitation by an auxiliary generator, of self-excitation, and of a differential compound-winding, instead of the desired hyperbola of equal power, a flat parabola for the different working speeds is obtained (fig. 12). The



...racteristics of ...s transmission. *Characteristics of R.Z.M. transmission.*

Fig. 12. — Characteristics of Gebus and R.Z.M. transmissions.

Explanation of German terms :

(Top, left) : Diagram showing the principle on which the Gebus transmission is designed. — 1. Generator. — *a)* Self-excitation shunt winding. — 2. Traction motors.

(Top, right) : Diagram showing the principle on which the R.Z.M. transmission is designed. — 1. Generator. — *a)* Self-excitation shunt winding; *b)* Separate excitation winding; *c)* Series winding. — 2. Auxiliary generator. — 3. Traction motors. — I, II. relays. — III. Resistance for separate excitation of main generator. — Generatorspannung = generator voltage. — Generatorström = generator current. — Drehzahldrückung = reduction of number of r.p.m.

voltage closely depends on the number of r.p.m., because, when the diesel engine speed decreases, the voltage of the exciter, and consequently the separate excitation decreases. But at the same time the self-excitation of the generator decreases, the reduction in the number of r.p.m. causing its voltage to drop also.

Mention should be made, in connection with this point, of two relays, which, by cutting in or out a resistance inserted in the circuit of the separate exciter, closely limit the zone of reduction of power, so that nearly a 100 % use of the power of the diesel engine is obtained within the main range of working conditions. Another advantage of this kind of transmission is that, apart from the two relays, it does not include any mobile parts.

In order that a train made up of several double railcars may be driven from one driver's compartment, the railcars have been equipped with a multiple-unit control system. The brakes and safety appliances are generally similar to those fitted on the first fast railcar. It has been possible, however, to further improve the air brake as well as the hand brake and the electro-magnetic rail brake. Likewise, the inductive automatic train control system has been perfected.

* * *

In a measure as the 13 new railcars were supplied, *the fast railcar services were extended.* On July 1st, 1935, the first of these vehicles replaced, on the Berlin-Hamburg line, the « Flying Hamburger », which, as stated, was sent to the Nuremberg Centenary Exhibition. On the same day, the new service was introduced on the Berlin-Cologne line. As a trial, the « Flying Hamburger » had, on June 17th, 1934, run non-stop over this line for the first time.

This run will ever mark a memorable date. Up to then, no railway vehicle had succeeded in running 576 km. (358 miles) non-stop; furthermore, the time allotted to make the run was only 4 3/4

hours, which means an overall speed of 122 km. (75.8 miles) an hour, in spite of the speed restrictions imposed in the Ruhr district, on account of the intricate lay-out of the lines. To this day the railcar which regularly serves this line constitutes *the fastest train in the whole world,* as it covers the 176 km. between Hanover and Hamm at an overall speed of 132.3 km. (82.2 miles) an hour, and the 254 km. (157.8 miles) from Berlin to Hanover at 131.4 km. (81.7 miles) an hour. The time spent to cover the Berlin-Cologne distance is not quite 5 hours, i.e. 5/4 hour less than the fastest steam train.

Little by little other fast services were introduced : Berlin to Francfort-on-Main on August 15th, 1935, and, coinciding with the introduction of the new time-tables in October of the same year, a fast service between Cologne, Hamburg and Altona. In this case it was found necessary for the first time to regularly use on the Cologne-Duisburg section, two double railcars coupled together and controlled from a single driver's compartment. Owing to increasing patronage of the railcar serving the Berlin-Cologne line it became necessary, even before the 1936 summer season, to couple up two railcars. Between Cologne and Duisburg, three railcars had to be coupled together; they were all driven from a single driver's compartment, no technical difficulties being encountered in this respect. When the 1936 summer timings were introduced, the time taken to make the Cologne-Berlin run was reduced to 4 3/4 hours.

Extensive preliminary tests had proved that the railcars were able to climb long and steep gradients, at the cost, it is true, of a heavy call on the machinery and brakes. This fact is the more remarkable that the vehicles had been built for high-speed running over flat country and that, when they were being designed, no such performances were considered. In view of these results, it became possible to tackle the question of fast services between Berlin and Munich, on which line — on the Thuringian Forest range — a 1 in 40 gradient 12 km. (7.5 miles) long is encountered. At the same time the fast services radiating from Berlin were extended to Stuttgart. Two coupled-up railcars were put into service; they are split up at Nuremberg, whence they run to Munich and Stuttgart separately. On the return run, both railcars are again coupled together at Nuremberg. Owing to the many curves and gradients met with in the German Central Mountain Mass, very high speeds are hardly practicable on this line, so that the overall speed between Berlin and Munich only slightly exceeds 100 km. (62 miles) an hour. Munich is nevertheless reached in 6 h. 39 m., i.e. in 5/4 hour less than by the fastest steam train. Figure 13 shows the runs made by fast railcars, the distances covered, the time spent, and the overall speeds.

The regular service towards Munich and Stuttgart was opened on May 15th, 1936. The daily distance covered by the railcars thereby increased considerably and today the two-unit railcars cover more than 220 000 km. (136 700 miles) per month. Figure 14 is a diagram showing the *distances run,* since July 1935, i.e. since the fast service to Cologne was opened. The various railcars have covered, on the average, over 150 000 km. (93 000 miles), and those that were supplied first have already reached 200 000 km. (124 000 miles). Up to now, these vehicles have covered together about 3 000 000 km. (1 860 000 miles) in regular service. Operation of the

Fig. 13. — High-speed railcar services on the German State Railways (1936 summer).

o. of rain.	LINE.	Distances.		Time spent.		Overall speed.		Remarks.
		Km.	Miles.	Hours.	Min.	Km./h.	M.p.h.	
1	2	3	4	5	6	7	8	9
VDt 1	Hamburg Hbf-Berlin Leb. . .	286.8	178.2	2	17	125.6	78.1	...
VDt 2	Berlin Leb.-Hamburg Hbf. . .	286.8	178.2	2	17	125.6	78.1	...
Dt 37	Cologne Hbf.-Hamburg Hbf. .	450	279.6	4	35	98.4	61.1	...
Dt 38	Hamburg Hbf.-Cologne Hbf. .	450	279.6	4	32	99.0	61.5	...
Dt 15	Cologne Hbf.-Berlin Zoo. . .	579	359 8	5	9	112.2	69.7	Via Essen.
Dt 17	Cologne Hbf.-Berlin Zoo. . .	550.5	342.1	4	50	113.8	70.7	Via Wuppertal.
Dt 15	(Hamm-Hanover)	176.4	109.6	1	20	*132.3*	*82.2*	...
Dt 16	Berlin Zoo-Cologne Hbf. . . .	579	359.8	4	55	117.6	73.1	Via Essen.
Dt 18	Berlin Zoo-Cologne Hbf. . . .	550.5	342.1	4	44	116.2	72.2	Via Wuppertal.
Dt 16	(Berlin Zoo-Hanover). . . .	254.1	157.9	1	56	*131 4*	*81.7*	...
Dt 571	Francfort (Main)-Berlin Ahb.	539	334.9	5	6	105.7	65.7	...
Dt 572	Berlin Ahb-Frankfort (Main).	539	334.9	5	3	106.7	66.3	...
Dt 551	Munich-Nuremberg-Leipzig-Berlin Ahb.	674	418.8	6	43	100.2	62.3	...
Dt 552	Berlin Ahb.-Leipzig-Nuremberg-Munich	674	418.8	6	39	101.4	63.0	...
Dt 711	Stuttgart-Nuremberg-Leipzig Berlin Ahb.	678	421.3	7	6	95.4	59.3	...
Dt 712	Berlin Ahb.-Leipzig-Nuremberg-Stuttgart	678	421.3	7	2	96.6	60.0	...
Dt 46	Beuthen-Breslau-Berlin Schl. .	508	315.7	4	21	116.8	72.6	...
Dt 45	Berlin Schl.-Breslau-Beuthen .	508	315.7	4	21	116.8	72.6	...

Reichsbahn without fast railcars can no longer be thought of. Figure 15 shows

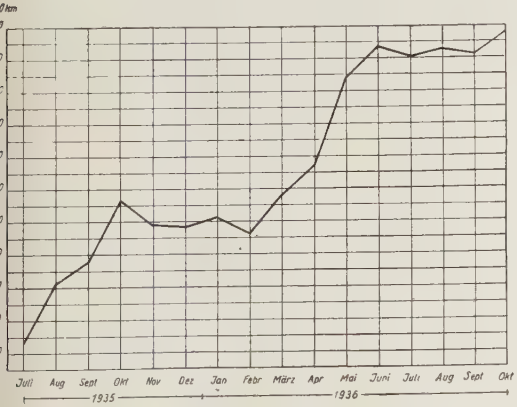


Fig. 14. — Diagram showing the distances covered by fast diesel-electric double railcars.

the fast services operated at present by the Reichsbahn.

The patronage of the different vehicles has increased in such a way that, on the Berlin-Cologne line, for instance, all the seats in both vehicles are nearly always booked in advance. The question of providing railcars of larger capacity was therefore investigated. By using an intermediate coach, the 2-unit railcars were converted into fast triplets (fig. 16). With a total length of about 60 m. (196′ 10″), this rake provides 109 third-class and 30 second-class seats. (fig. 17). The 2nd-class seats are contained in separate compartments (fig. 18); in respect of third-class, the large open compartment has been retained (fig. 19). All

vehicles have wide side corridors. Further, they contain a kitchen with pantry, as well as a luggage and mail compartment. The rake is equipped with two Jakobs (common) bogies.

Obviously, a horse-power of about 2×400 was not sufficient for a triple unit. The Maybach Works perfected a diesel engine of about 600-H.P., the outside dimensions of which, as regards length and width, are practically equal to those of the 410-H.P. engine, so that it could still be carried in the bogie.

The increase in power was obtained by raising the mean effective pressure; to this end, in addition to a slight increase in the swept volume, the engine was supercharged. The supercharging turbo-blower is driven by an exhaust-gas

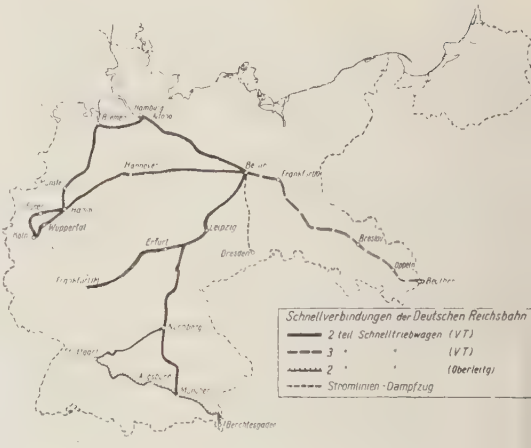


Fig. 15. — Fast services on the Reichsbahn.

Explanation :

2 teil (3 teil) Schnelltriebwagen = double (triple) fast railcars. — Stromlinien-Dampfzug = streamlined steam train. — 2 teil... Oberleitg. = double motor coach, overhead contact line.

Fig. 16. — Fast triple railcar.

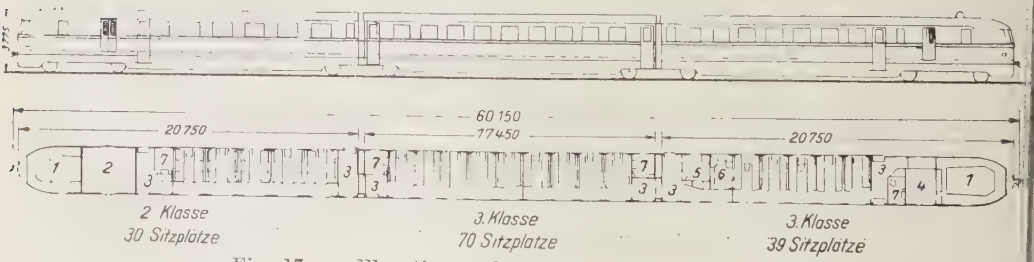


Fig. 17. — Elevation and plan of fast triple railcar.

Note. — Sitzplätze = seats.

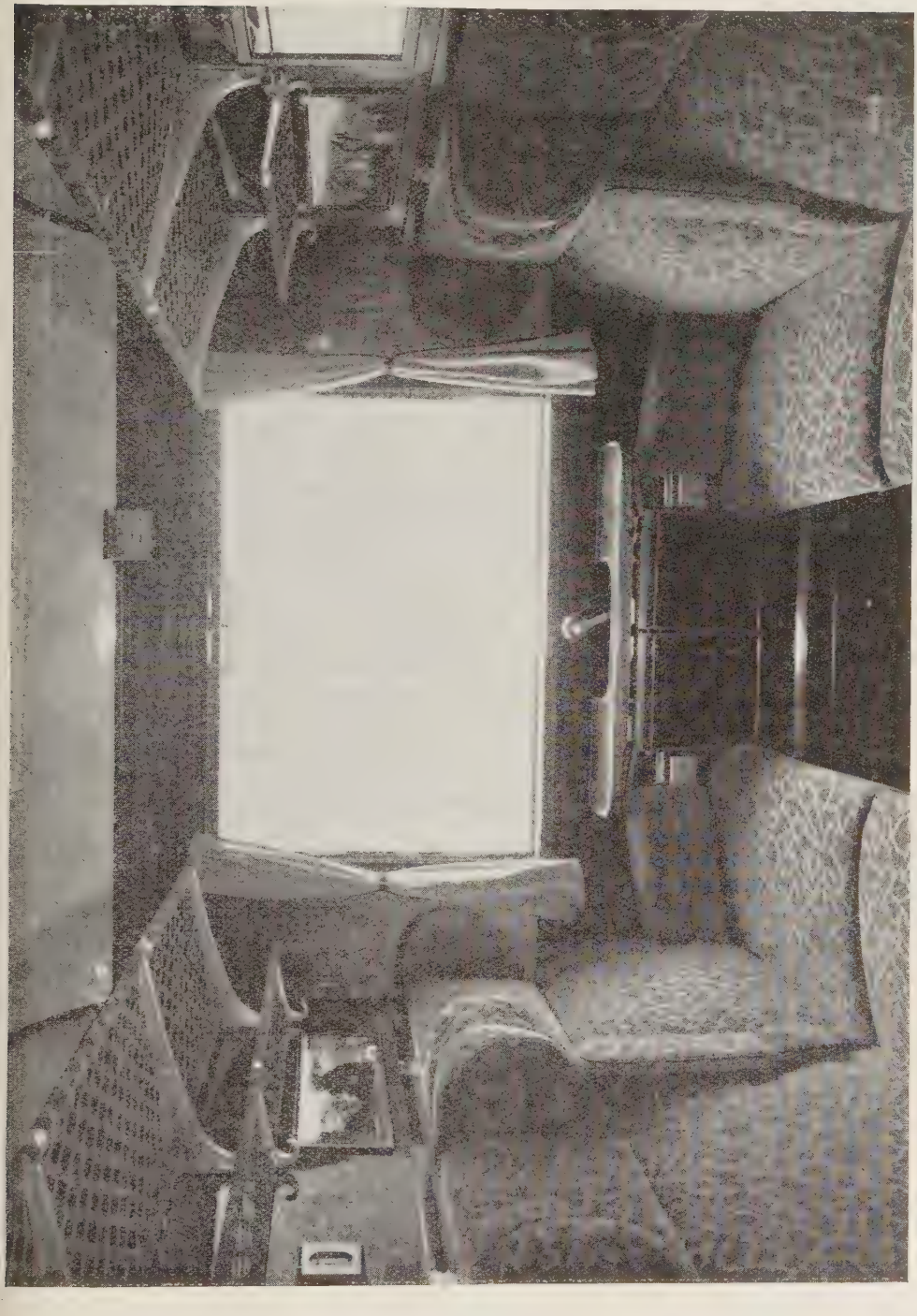


Fig. 18. — 2nd-class compartment in fast triple railcar.

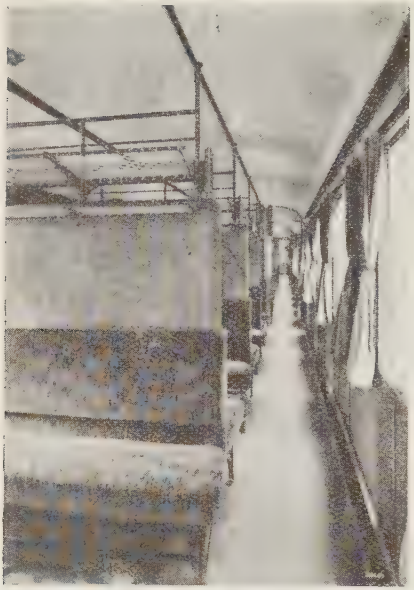


Fig. 19. — Large open 3rd-class compartment with side corridor in fast triple railcar.

turbine which makes about 13 000 r.p.m. under full load. The combustion air is forced into the engine under an overpressure of about 0.4 kgr./cm² (5.6 lb. per sq. in.). The turbine and turbo-blower are located between the two banks of cylinders, so that the pipes for the precompressed air as well as for the exhaust gases are very short. The exhaust gases are sufficiently expanded in the exhaust-gas turbine for a special muffler to become useless. The various parts of the motion are the same as in the 410-H.P. engine, seeing that the maximum pressure has not been increased.

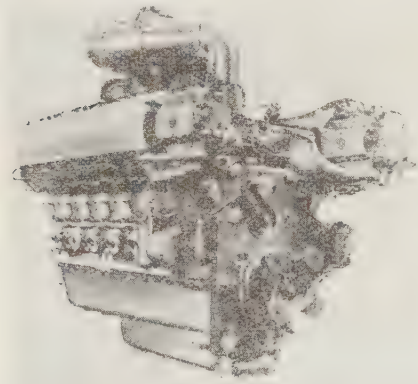


Fig. 20. — Maybach GO 6 type 600-H.P. supercharged diesel engine.

As regards thermal efficiency, there is nothing to be feared, in spite of the higher specific power of each cylinder as, like in the case of the two-stroke system with special scavenging pump, the advance opening of the admission valve at the end of the stroke produces a powerful scavenging effect upon the cylinder. Not only are the combustion gases radically exhausted, but the piston face and cylinder walls are efficaciously cooled. Furthermore, the scavenging air reduces the very high temperatures inside the exhaust-gas turbine. The usual method employed in the 410-H.P. Maybach engines for cooling the lubricating oil in the crank case, by means of the combustion air taken in, could no longer be used for supercharged engines. It was consequently found necessary to fit on the front of the engine a turbo-blower coupled to the crankshaft, which sucks in the cooling air through the crank case.

In order to be able to draw a comparison between the different systems of transmissions that could be used with such powers, it was decided to equip two of the fast triplets under construction with electric transmission, and two others with hydraulic transmission.

The electric transmission was designed on the same principles as that of the twin-railcars, a generator of higher power being used to suit the 600-H.P. diesel

engine, and also two traction motors per generator. The R.Z.M. type of electric transmission was retained.

On the other hand, the hydraulic transmission had to be specially designed for this case (fig. 21). We take it that the principle on which this kind of transmission is designed is well known. In order to reduce as much as possible the dimensions of the transmission, the number of r.p.m from the diesel driving shaft was increased by installing a gear between the engine and converters. Good efficiency was obtained by dividing the

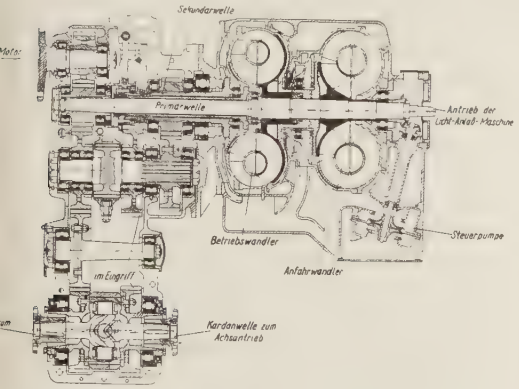


Fig. 21. — Voith-Triebwagenbau A.G. type hydraulic transmission with preliminary gearing and toothed reverse gear for fast triple railcars.

Note. — Vom motor = from engine. — Kardanwelle zum Achsantrieb = cardan shaft driving the axle. — Im Eingriff = in mesh. — Primär (sekundär) Welle = driving (driven) shaft. — Betriebs (Anfahr) Wandler = running (starting) torque converter. — Antrieb der Licht-Anlass-Maschine = drive of lighting plant and starter. — Steuerpumpe = control pump.

hydraulic part into 2 torque converters, i.e. the accelerating converter for the speed range between starting and 108 km. (67 miles) an hour, and the normal working converter for 108 to 160 km. (67 to 100 miles) an hour (fig 22). The transition from one converter to the other is effected automatically, according to the number of r.p.m. of the secondary shaft. For reversing, the mechanism has two spur gear sets which can be engaged at will, while the gearbox is at rest, by means of a claw coupling. Owing to the high power — 600-H.P. — of each mechanical equipment, both axles of the motor bogie had to be driving axles, as otherwise the power developed could not have been used at low speeds for lack of adhesive weight. In order to still have cardan shafts of sufficient length for driving the axle, the wheelbase of the bogies had to be increased to 4.23 m. (13′ 10 1/2″) (fig. 23).

The driving power is governed in an identical way with the electric transmission and the hydraulic transmission, in that only the number of r.p.m. of the diesel engine is altered, and this by

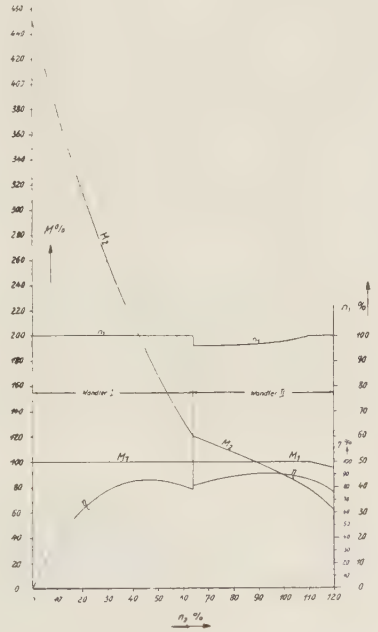


Fig. 22. — Characteristic curves of hydraulic transmission for fast triple railcars.

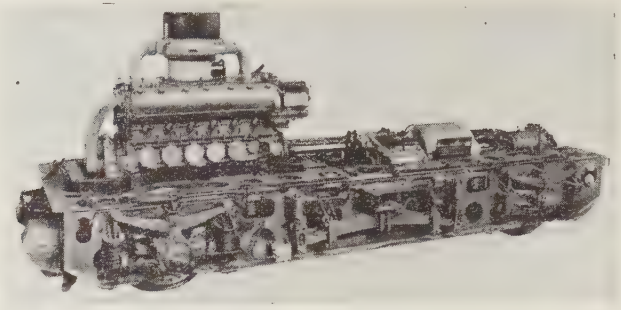


Fig. 23. — Driving bogie of fast triple diesel-hydraulic railcar.

means of the same speed-governing servo-motors.

This combination allows of two railcars equipped with different systems of transmission being coupled together and controlled from a single driver's compartment.

New methods had to be devised for ventilating the triple railcars, as with the hydraulic transmission it was no longer possible to use the generator cooling fan as a suction ventilator for exhausting the air from the coaches. In this new type of railcar the ventilation was combined with the heating by forcing in air which had been filtered, and if need be preheated by a special air heater, the heat from which is carried by the mechanical equipment cooling water. An oil-fired hot-water boiler placed under the body of the vehicle, and the burner of which is put automatically into or out of action, according to the temperature of the cooling water, maintains the latter at a uniform temperature. An advantage of this system is that after a vehicle has been standing still for a long period in winter, the temperature of the cooling water can, by the use of this standby boiler, be brought up to a temperature of 50 to 60°, necessary for the machinery. The air forced into the coaches is kept

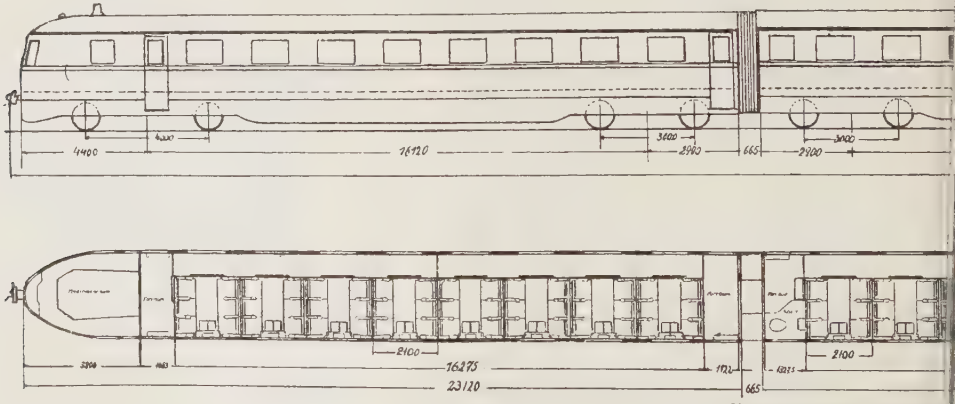


Fig. 24. Elevati

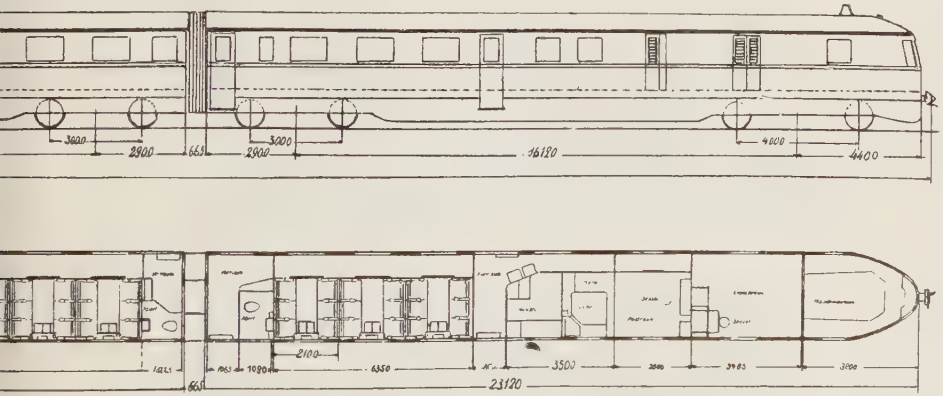
at a fixed constant temperature, by adding, if need be, cold air. In summer, the coaches are only ventilated by means of filtered air.

The brakes and other safety appliances on the triple railcars are the same as on the twin railcars, with the improvements deemed useful so far.

The weight in working order of the triple railcar with hydraulic transmission is 119 t. (117.1 Engl. tons). With electric transmission this weight is 129.5 t. (127.5 Engl. tons), i.e. about 9 % higher. The first of these vehicles equipped with electric transmission was supplied at the end of 1935. The results of the trial runs were remarkable. These trials brought out the difference between the double and triple vehicles, and the effect of the old and new shape of the coaches.

At high speeds, the running resistance, hence the vehicle weight, are of secondary importance. As regards air resistance, most of it is exerted upon the surfaces which are perpendicular to the running direction, which surfaces are the same for the double and triple railcars, whereas the lateral surfaces, which are about one third longer in the case of the triplets, only slightly increase the air resistance due to friction on these surfaces. After a number of trials carried out coasting or at constant speed on a level track section, the air resistance coefficient c^{∞} has been given a value 0.58 in the case of the first « Flying Hamburger », and of 0.6 for the fast triplets. It should be borne in mind that the outside shape of the latter is appreciably better, from the aerodynamic point of view, as the original « Flying Hamburger » only had a lateral apron and no shrouding under the car body. In addition, the ends of the triplets have a better shape. Special test runs have revealed, for example, that after the side aprons had been removed, the air resistance coefficient of the « Flying Hamburger » increased from 0.58 to 0.62.

In the course of a test run, on February 17th, 1936, the triple railcar with electric transmission reached a speed exceeding 200 km. (124 miles) an hour. This was the first time that a railway vehicle designed for regular service passed the 200-km. limit. It was found necessary, it is true, to alter the working conditions of the electrical plant by increasing the self-excitation of the generators, as otherwise, owing to the drop-



ilcars built in 1936.

ping characteristics of the R.Z.M. transmission, it would not have been possible to use the full power of the diesel engine with the high number of r.p.m. of the traction motors and the corresponding increase in voltage. The power developed at this speed by the generators was 376 kw. A particularly remarkable fact was the so perfectly smooth riding of the vehicle at this speed that people in the railcar would never have thought they were moving at 124 miles an hour if the various precision instruments had not shown and recorded such speed.

Up to now, the fast triple railcars have only been in service for three months on the Berlin-Beuthen line, so that no operating results are available at present.

The future development of ultra-fast railcars on the Reichsbahn raises the problem of designing triple railcars with about 120 second-class seats and the necessary accessory compartments. Owing to the relatively greater length of the different bodies, the bogie of the Jakobs type will have to be abandoned, in spite of the good results it has given so far, and each body will have to be carried on two independent four-wheeled bogies. Likewise, the large open compartment will no longer exist in these vehicles. It will be replaced by roomy separate compartments, 2.10 m. (6′ 7″) long, with 6 seats, and a wide lateral corridor. The kitchen will also be enlarged, which will provide greater facilities for the passengers.

As regards the mechanical plant, these railcars will have the same diesel-electric equipment, with two 600-H.P. engines, as the triplets with two Jakobs (common) bogies we have dealt with. It is reckoned that these new triplets will be put into service towards the end of 1937 (fig. 24).

In the meantime, it will probably be possible to test a radically different type of railcar. An articulated rake of four coaches is being built at present, one vehicle of which will be the driving unit, while the others will be used for carrying passengers. Each rake provides 130 second-class seats, in separate compart-

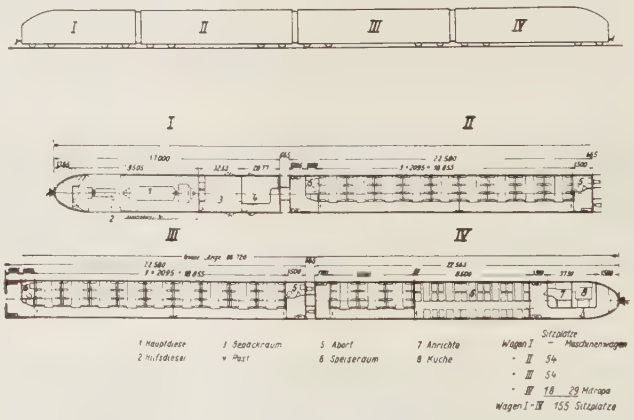


Fig. 25. — Plan of fast quadruple railcar.

Translation of legend:

1. Main diesel engine. — 2. Auxiliary diesel engine. — 3. Luggage compartment. — 4. Mail compartment. — 5. Lavatory. — 6. Restaurant. — 7. Pantry. — 8. Kitchen. — Sitzplätze = seats. — Wagen = coach. — Maschinenwagen = power vehicle.

ments containing 6 seats each, and has a side corridor and a separate dining room seating 25 passengers (fig. 25).

The engine room contains an eight-cylinder low-speed diesel engine with supercharging turbo-blower. The engine develops 1 300-h.p. at 900 r.p.m.; for driving the accessory apparatus, a 150-h.p. auxiliary engine is provided. Electric transmission has been selected because it allows of the tractive power being distributed uniformly over the whole rake between different bogies. Consequently, this motor rake, about 85 m. (278′ 9″) long, will be able to run safely in both directions, even at high speeds, although the power generating set is concentrated at one end of it, in the power vehicle. The coupling between the latter and the passenger-carrying vehicles is so arranged that the power vehicle can be changed on any service track within a minimum of time.

The putting into service of fast diesel railcars only represents, it is true, one of the factors of the operation of the Reichsbahn. Nonetheless, this quite recent method of transport has come much to the fore as regards public interest and also from the technical point of view.

Within a relatively short time, in a new field of railway technics, exceptional results were obtained, which have made the high-speed railcar a method of transport second to no other rail vehicle.

[621. 135.2 (.436) & 625. 215 (.436)]

New axle-bearings on locomotives and railcars of the Austrian Federal Railways,

by F. STRAUSS, M.E., Vienna.

The axle-bearings of railway rolling stock operate under far more exacting conditions than the bearings on stationary machinery. They are subject to heavy loads and violent shocks and must withstand rough handling and the influence of the weather as well as the penetration of dust, grit and water.

If for no other reason, a modern design of axle-bearings deserves particular attention, because recent developments in railway practice call both for heavy axle loads and high travelling speeds.

Bearings working under such conditions naturally require special provisions in regard to their lubrication. The latter must meet, not only the more difficult operating conditions as far as its action is concerned, but also the requirements in regard to economy, by doing away with the costs of upkeep such as, e.g., those caused by the renewal of lubricating pads as used up to the present. Moreover, it must safeguard utmost economy in oil consumption.

Furthermore, there is the obvious condition that modern axle-bearings, in spite of all improvements, must be as simple to fit as the pad-lubricated bearings hitherto employed.

The Austrian Federal Railways had already carried out a series of practical experiments with pad-less bearings several years ago. On the strength of these tests, they proceeded to adopt such bearings on a large scale, all the electric locomotives, steam locomotives and other motive power, as well as passenger coaches, luggage vans, and also part of the wagons built by the Austrian Federal Railways in recent years having been equipped with *Friedmann* type axle-bearings. The Austrian Federal Railways obtain with these bearings at high speed, and under heavy axle loads, very good results. Bearings of the same type have, incidentally, also been adopted by Railways in other countries, for instance by the Czechoslovak State Railways, the Swiss Federal Railways, the Est Railways (France), the P.O.-Midi Railways, the Paris-Lyon-Méditerranée Railways, and the Belgian National Railways Company.

The *Friedmann* type bearings are equipped with circulating lubrication feeding the oil under pressure. The functioning of the lubricating arrangement is, in principle identical both with the axle-bearings arranged outside of the wheels (the so-called outside axle-bearings) and with axle-bearings located between the wheels (the so-called inside axle-bearings); however, the single component parts are naturally of different design. Thus, e.g., one-piece axle-box bodies and a lubricating device arranged in the cover can be used for outside axle-bearings, whilst the casing of inside bearings must be made in two parts, and in the absence of a cover, the lubricating device had to be arranged in a different manner.

Figure 1 is a view of an outside axle-

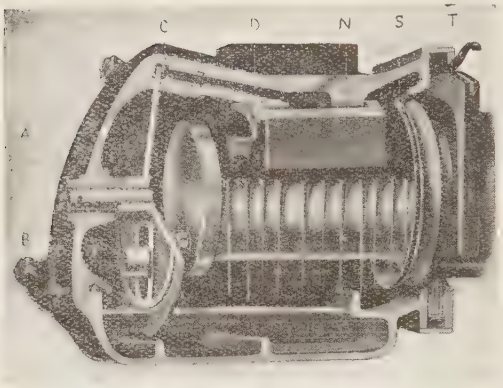


Fig. 1.

bearing such as used on coaches and wagons, tenders and the like.

Figures 2 and 3 show actual applications to such vehicles.

Figure 4 shows an application to an electric locomotive.

The bearing shown in figure 1 mainly consists of a cast-steel casing with an amply dimensioned oil chamber, the brass with white-metal lining, a cover with the lubricating arrangement and a sealing device. The dimensions of the bearing can be adapted to suit any existing vehicle. The inclined position of the cover affords the advantage that the cover gasket is not submerged in oil, and that no oil is wasted on taking off the cover.

The cover, as mentioned above, contains the lubricating arrangement. The latter, unlike other existing systems, does not consist of a centrifugal rod, causing the oil to foam, but of an impeller disk « A », which conveys the oil in a powerful and calm jet to the brass. The impeller disk is rotated by a driving pin « B » fastened to the front of the journal.

The oil impeller disk dips into the oil sump of the axle-box, carrying the lu-

Fig. 2.

Fig. 3.

Fig. 4.

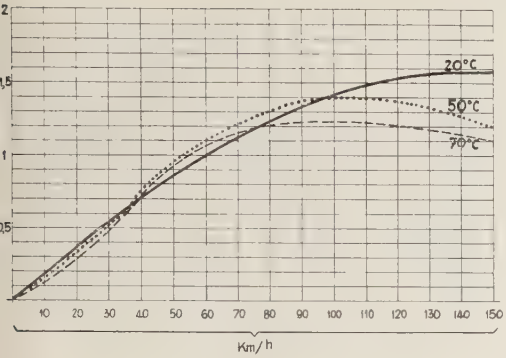


Fig. 5.

bricating oil, according to its direction of rotation, into one or the other of the two pressure pockets « C » arranged in the cover. The oil pressure is produced by the special configuration of the pockets, which are so shaped that the oil continually delivered by the disk cannot pass radially towards the interior, nor into the opposite pocket, because at the topmost point between the two pockets there is a restricted portion just wide enough to allow the disk to pass.

The delivery of oil to the brass starts directly the vehicle begins to move, and it increases almost proportionally with the travelling speed. The pressure builds up automatically as the viscosity of the oil increases.

Figure 5 shows the increase in the amount of oil delivered at progressive speed and various temperatures.

This device will, therefore, work at all speeds occurring in actual service, and it is also independent of the viscosity and quality of the oil used.

In view of the ample circulation of oil, particular care was given to the design of the sealing device. The latter consists of two parts, viz. :

(1) A splash ring « S », which has been designed from special points of view, and which, together with the surrounding portion of the casing, forms a definite unit.

(2) A sealing device « T » inserted in the dust-guard pocket.

The purpose of the splash ring is to throw off all the oil which flows back

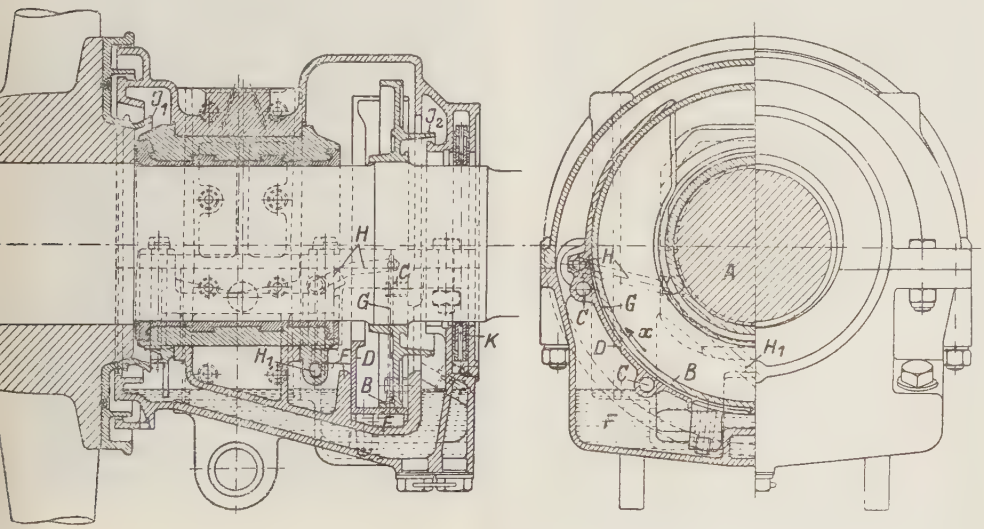


Fig. 6.

in rather large quantities from the brass towards the pocket, and to return it into the casing. To ensure this effect, the shape of the splash ring and particularly the manner in which it is arranged in relation to the adjacent portions of the casing, and furthermore the configuration of the latter near the pocket, are of great importance, and have been determined after extensive experiments.

The sealing device « T » in the pocket is not a seal against oil, as this cannot get into the pocket, but is merely a dust-guard. This device also keeps out water from the interior of the axle-box body by allowing drops of water which may find their way into the pocket between the hub and the dust-guard to escape through a small hole at the bottom of the pocket.

These bearings may remain in service between the regular periodical inspections, without replenishing the oil and without any attention whatever. The supply of oil is not only kept up as far as quantity is concerned, but it also retains its full lubricating properties, as owing to the uniform action of the impeller disk a calm flow of oil is effected, the oil being neither whipped nor mixed with air. By this means, any deterioration of the oil due to oxidation is avoided. This results in an important saving in oil and in the cost of attendance.

As the progressive delivery of oil to the bearing brass and to the journal, which increases in proportion to the revolving speed, i.e. the travelling speed, effects a reliable and ample flushing with oil, which keeps the temperature of the bearing at an extremely low level, failures caused by hot boxes, which, as is known, entail considerable costs, are avoided. The fluid friction safeguarded by the flushing of the journal likewise tends to diminish the temperature of th bearing and reduces the wear of th brass and of the journal to a minimum

The use of lubricating pads being dis pensed with, the expense for the frequen renewal of these parts is likewise saved

Figure 6 is a diagrammatic view of locomotive axle-bearing with force-fee circulating lubrication fitted between th wheels, as used on all steam locomotive of the Austrian Federal Railways buil in recent years. Figure 7 shows such

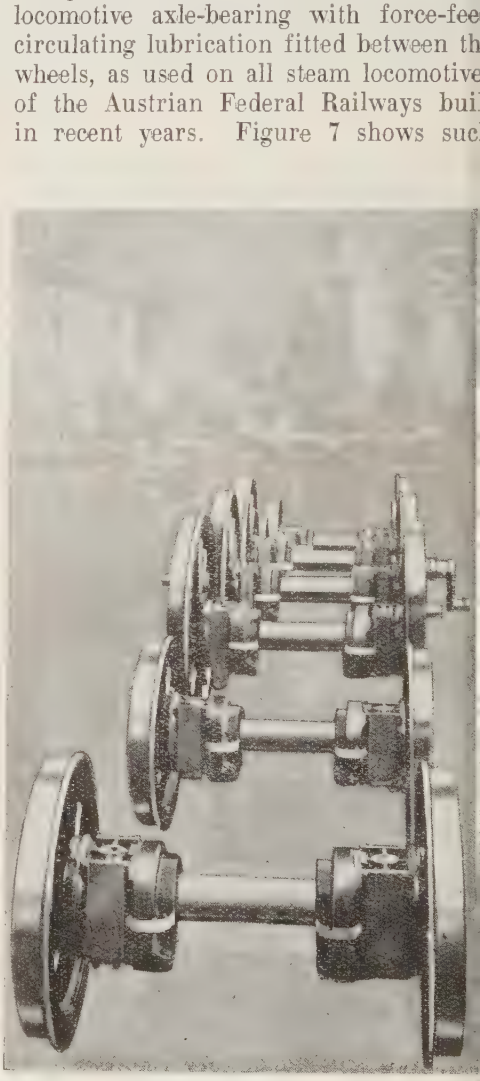


Fig. 7.

inside axle-bearings fitted to the axles of class 729 locomotives.

The bearings previously used were pad-lubricated bearings, fed by mechanical lubricators. This system of lubrication, while entirely satisfactory, required careful attention, and the oil-consumption was still comparatively high, due to the imperfect sealing. Nor could the lubricating pads fully meet the requirements at high speed, under heavy loads and on curved track.

These difficulties are overcome by the *Friedmann* bearings with force-feed lubrication. These bearings are fitted throughout with particularly efficient seals and, owing to the abundant circulation of oil and the resulting ample lubrication and cooling, they are well suited for high speeds, heavy axle-loads and the greater strain on curved track. The oil consumption and the attention are reduced to a minimum.

The oil impeller drum B shrunk on the axle A is enclosed in an oil impeller casing D containing the pressure grooves G. The rotating drum B scoops the oil from the body of the axle box, forcing it through the pressure grooves G and the passages H into the bearing brass. The excess oil is led through the passage H_1 to the opposite side of the bearing brass, and returned into the oil sump of the axle-box.

To keep out dust, grit and water in a reliable manner, a system of labyrinth packing rings is arranged at the side facing the hub, whilst the opposite opening of the axle-bearing is provided with a multiple seal K.

In order to prevent any escape of oil through the two openings of the body of the axle-box, splash edges I_1 and I_2 returning the oil into the casing are arranged in the interior.

To enable the axle-bearing to be readily fitted, the body of the bearing is made in two parts, and it is provided with suitable spring seats or eyes for the spring hanger according to the arrangement of the suspension springs.

The oil well of the casing is amply dimensioned. This fact, in conjunction with the calm and uniform circulation of oil, with which any foaming and oxidation of the oil is avoided, results in the oil fully retaining its lubricating properties, as is also the case with the outside axle-bearings, owing to the same provisions.

Comparisons based on international railway statistics,

by Dr. Fritz LANDSBERG, Reichsbahnoberrat i. R., Berlin.

I. — General preliminary remarks.

Operating results of all kinds can be appreciated more accurately by comparisons; in fact, in many cases, this is the only possible way of doing so. Comparisons of this kind relate to either *different periods* or *different services*.

The *former* concern the same service or branch of a service and bring together the workings or the results over different periods.

The *latter* deal with different services or branches of a service, as far as possible those working under identical or similar conditions, and contrast them over equal periods. A distinction is made between a railway's own workings and those of foreign railways, according as the departments of one railway or different railways or services of different railways are compared with one another.

Frequently these two kinds of comparison are combined in order to obtain further information from them, and the comparisons are completed by statistics relating to the general economic situation, the growth of the branches considered, or other related industrial, professional and commercial branches.

This is done to bring together the data needed to trace the course of events to their causes and to reveal the way the facts are interconnected in the railway's own working or in other undertakings.

The *absolute numbers*, i.e., the results in their original form, cannot be used for such comparisons, especially when dealing with different railways. *Relative numbers*, representing in a comparable form both the conditions governing the working and the results obtained, are needed.

For railway services, with their voluminous international published statistics, these comparisons offer many possibilities of particular importance because of the close interdependence of the transport industry and the national economics.

II. — Application to railway working.

When comparing railways in different countries or regions, the following should be noted. Broadly speaking, the transport industry is based on geographical and geopolitical conditions, the density and distribution of the population, the richness of the soil and the industrial wealth of the country, the standard of living, etc. All this is reflected *in the nature of the railways themselves* and in their equipment, and influences the *operating results and the traffic*.

Consequently the *economic results* vary on the expenditure side with the index numbers relating to living, raw materials, wages, etc., and on the receipt side these factors must be taken into account in drawing up the rates.

The difficulty of taking all these factors into consideration when comparing a certain number of railways is avoided or reduced by using *ratios*.

We would like to remind our readers that we published an article in the November 1935 English edition of the *Bulletin*, in which we described as *first-de-*

gree ratios those dealing with the same sphere of activity or the same administrative department (permanent way, working, traffic, expenditure, receipts, staff); as they nearly always characteristise, as parts of total numbers, the field under consideration, we will call them hereafter « *characteristics* ».

On the other hand, the ratios which enable different fields to be compared were designated as *second-degree ratios;* as they enable us to appreciate the results and evaluate them, we will call them « *values* » hereafter ».

The particular nature of the *characteristics* and *values* can be easily appreciated when examining the examples quoted below, by the way the different ideas are built up.

We give below the actual working out of a system for calculating these numbers. The actual data used for this purpose have been taken from the statistics of the International Railway Union (U.I.C.); the figures have been compiled and grouped on the same bases and any divergences are explained. Besides the absolute numbers, which occupy the larger place in the U. I. C. statistics, ratios are also given, but these are not sufficient for making financial comparisons, as they do not give all the necessary relations; nor are they systematically developed and presented for the question with which we are dealing.

In order to appreciate the extent to which the characteristics and values can be used, we have calculated them and have brought the results together in the tables given for 11 European main-line Railways. The limitations imposed by the available information are brought out as well; they are only sufficient for making restricted and sometimes general comparisons.

In most cases, it would be quite easy to get a better economic evaluation of the work done by using certain operating figures drawn from the annual reports. These documents should be consulted, therefore, in the present state of affairs, to make the comparisons more precise and circumscribed, and when carrying out special investigations. Examples in connection with the way the locomotives and wagons are used were given in the November 1935 and April 1936 numbers of this *Bulletin* (English edition).

In the interests of the systematic use of statistics as well as of scientific accuracy, the following remarks on the subject of the « values » should be made :

Values are grouped in the tables under the general heading « Use » of the installations and organisations. The word « use » is only a makeshift, as we have only mentioned the results related to one of the units given in the statistics, for example : the distances covered by the trains per kilometre of lines, the number of vehicles per train, the annual distance covered by the vehicles, etc.

We explained the scientific idea of « use » in the article in the April 1936 *Bulletin,* and in this sense, the ratio for example, « of the useful load to the tonnage of wagons » could only be considered as part of the use, i.e. as a degree of intensity. This again is not exact, seeing it was necessary to calculate the tonnage as an average of the total wagon stock, which differs from the average tonnage of the wagons actually supplied.

To complete the idea of « use » it is also necessary to take into account the « degree of time », i.e. the ratio of the *period* of actual *service* to the period of possible service.

The values, therefore, in the scientific sense are only important parts of the use, to which it is necessary to limit oneself when using the U.I.C. statistics which supply, after all, a basis of comparison.

III. — Practical test of comparative statistics.

In arranging the tables hereafter, we followed the U.I.C. system so that they can be used conjointly. We reproduced with the *characteristics* the important totals to which the parts relate, so that it is possible to see immediately, against each part, its order of magnitude, and to take this into account in the comparative investigation.

The whole of the numerical data are taken from the U.I.C. statistics for 1932. The descriptions of the tables as well as the numbers of the different railways also are the same as those used by the Union. These numbers are the following :

3 = Deutsche Reichsbahn.
5 = Belgian National Rys. Co.
23 = French State Rys.
25 = French Nord Ry.
26 = P. L. M. Rys.
27 = Paris-Orléans Rys.
28 = Great Western Ry.
29 = London & North Eastern Ry.
30 = London, Midland and Scottish Ry.
31 = Southern Railway.
36 = Italian State Rys.

In comparing the Railways for one year only (1932), we wished to show that this comparison was made possible by bringing together the « characteristics » and « values ». A detailed examination of the different ratios, or in other words the analysis of the facts revealed by the comparison, are outside the scope of this article and we will leave this to the competent reader.

The enlarging of this comparison between railways by extending the study of the values to several years, accompanied by consideration of the various railways, separately and together, will throw valuable light on the repercussion of changes in the legal and economic bases and in domestic and foreign policies on the economic conditions and the structure of the railways; the comparative and scientific investigation of the forces in play and of their influence on the railways of the different countries will also bring out useful basic conclusions and justify once again the use of statistics as a tool for this purpose, although it means a considerable amount of work at much cost (*).

(*) The wish for numeral ratios has already been expressed elsewhere; see : 3rd Committee of accounts, sub-committee of the general statistics. — Sixth report for the Meeting at Nice in 1930, chapter VII, « International Statistical Institute » (I.I.C.) Reporter Girard : « His proposals consider extending certain numerical tables of the U.I.C. (addition of the relative numbers of passengers, indication by classes of the average length of the journeys, etc.) »

TABLE I. —

—	—	No. 3	5	23	25
1-1. Railways (V+S)					
Length of lines. . . .	Km.	53 885	4 831	9 134	3 830
Length of track . . .	%	234	285	192	273
running.	%	144	162	145	168
on the level	%	29.6	21.2	24.5	18
straight.	%	68.8	64.6	63.2	68.1
1-2. Motive power (V+S)					
(a) Steam locom. :	Units	21 044	3 876	3 597	2 761
With separate tender .	%	61.3	72	82	74.6
Tank locomotives . . .	%	38.7	28	18	25.4
Loc. with separate tender :					
4-coupled	%	0.2	4	5.7	3.4
6-coupled	%	20.3	30	41.5	26.6
8 or more coupled wheels	%	40.8	38	34.8	44.6
Tank locomotives :					
4-coupled	%	1.3	3 8	0.5	5.7
6-coupled	%	19.2	11.7	10.5	6.8
8 or more coupled wheels	%	18.2	12.5	7.0	12.9
(b) Electric locom. :	Units	400	— —	39	— —
as a % of *(a)* + *(b)* .	%	1.87	...	1.08	...
(c) Railcars :	Units	1 421	7	275	12
1-3. Rolling stock.					
Passenger carriages (V + S).	Units	67 025	8 473	7 079	5 195
4-wheeled	%	32.0	10.7	52.4	68.8
6-wheeled	%	48.6	81.0	9.8	12.1
8-wheeled	%	19.0	8.27	37.4	24.5
12-wheeled	%	0.4	0.03	0.4	0.6
Total number of seats :	Number	3 812 343	455 207	388 666	304 007
1st-class	%	0.5	4.05	12.5	10.4
2nd-class.	%	11.1	16.95	30.2	20.5
3rd-class.	%	88.4	79.0	57.3	69.1
Average number of axles per	Carriage.	2.87	2.96	2.85	2.64
Average number of seats per	Axle.	20	18.1	19.1	22.2
Goods wagons (V only) :	Units	621 392	114 065	82 185	87 512
Covered	%	33.2	33.34	44.42	29.5
Open	%	60.6	66.60	52 90	66.0
Special	%	6.2	0.06	2.68	4.5
Average number of axles per wagon	Number	2.04	2.7	2.26	2.29
Average tonnage per axle	Tons.	8.1	8.1	7.6	8.4

Note. — ? = not stated; — — = nil.

racteristics.

26	27	28	29	30	31	36
9 838	7 878	6 074	10 222	11 123	3 510	16 886
210	175	240	264	282	246	?
155	141	171	181	194	189	126
19	25.6	?	?	?	?	23.3
60	62.4	?	?	?	?	68.0
5 649	2 357	3 754	7 094	8 450	1 999	5 333
84.5	82	37.4	68.5	64.8	58.0	71.2
15.5	18	62.6	31.5	35.2	42.0	28.8
2.2	11.7	5.6	12.6	11.4	27.6	0.6
25.1	35.7	28.1	45.6	37.7	30.4	34.8
57.2	34.6	3.7	10.3	15.7	...	36 8
— —	0.5	5.6	10.7	10.0	25.7	0 4
7.1	4.5	51.6	19.9	24 8	15.6	24.2
8.4	13.0	5.4	0.9	0.4	0.7	4 2
37	218	— —	13	— —	— —	895
0 65	8.47	— —	0.15	— —	— —	14.4
165	96	53	178	328	1 033	88
8 270	4 198	6 343	11 976	18 679	7 068	8 362
10.4	68.9	10.3	4.1	2.1	1.3	15.2
65.0	3.7	4.2	26.2	5.9	6.5	6.8
24.6	26.0	85.2	65.4	89.3	92.2	78.0
...	1.4	0.3	4.3	2.7	— —	— —
58 347	254 421	357 129	702 275	1 105 847	411 859	501 574
10.5	8.9	11.1	11.7	12.3	18.1	8.25
24.5	19.1	...	6.7	0 2	0.4	28.15
65.0	72.0	88.9	81.6	87.5	81.5	63.60
3 14	2.64	3.73	3.85	3.95	3.9	3.63
17.6	23.3	15	15.2	15	14.2	16.6
37 051	57 205	81 105	258 776	276 973	33 782	143 037
43.4	52.5	26.4	13.6	15.4	14 9	45.2
54.9	46.9	65.0	77.1	78.7	77.2	50.5
1.7	0 6	8.6	9.3	5.9	7.9	4.3
2.12	2 16	2.06	2.02	2.02	2.01	2.03
8 0	7.7	5.4	6.1	5.5	5.4	9.0

TABLE II. –

—	—	No. 3		5	23		25
Work done.							
2-1. Trains, locomotives, railcars (V) :							
Total distance covered by trains :	1000 km.	610 370		65 416	70 540		55 894
Passenger services . . .	%	67.86		68.4	65.5		57 2
Goods services.	%	31.00		31.0	34.2		40.9
Other services	%	1.14		0.6	0.3		1.9
Distance run by locomotives and railcars, including shunting	1000 km.	812 397		88 979	90 381		76 439
steam traction.	%	92.1		99.3	88.4		99.49
electric traction	%	2.3		— —	0.6		— —
railcars	%	5 6		0.7	11.0		0.51
Distances run by locomot. :		S	E	S	S	E	S
working trains	%	73.6	85.8	73.4	80.5	83.8	73.0
assisting.	%	0.4	0.2	2.8	0.4	1.5	1.2
light	%	4.8	5.0	5.0	8.9	9.4	7.4
shunting.	%	21.2	9.0	18.8	10.2	5.3	18.4
2-1. Vehicles (V) :							
Distances run by passenger coaches	Millions of coach-km.	2 410.0		?	255.5		242.0
Distances run by goods wagons	Millions of wagon-km.	6 300		?	915.9		970
loaded.	%	70.3		?	73.2		66
empty.	%	29.7		?	26.8		34
Traffic worked							
2-2. Passenger traffic (V+S) :							
Passenger-km	Millions of km.	30 811		5 171	5 231		3 893
1st-class	%	0 2		0.8	4.6		3.1
2nd-class.	%	6.4		12.1	23.5		14.5
3rd-class	%	94.4		87.1	71.9		82.4
2-3. Goods traffic (V+S) :							
Tonnes-km., total	Millions	44 411		5 230	2 613		7 109
parcels and fast goods .	%	0.9		?	9.5		2.1
slow goods	%	86.7		?	81.3		94.0
service transports . . .	%	12.4		?	9.2		3.9

Note. — ? = not stated; — — = nil: S = steam; E = electric.

acteristics.

26	27	28	29	30	31	36
13 253	61 988	98 987	164 131	228 387	99 195	132 598
68.2	67.4	64.3	61.3	64.1	88.5	68.1
30.6	31.8	35.7	38 7	35.9	11.5	31.3
1.2	0.8	— —	— —	— —	— —	0.6
40 439	75 454	134 491	221 905	312 523	116 675	168 915
99.1	82.6	98.6	97.1	96.0	97.1	81.7
0.9	11.4	...	0.1	...	0.1	16.8
— —	6.0	1.4	2.8	4.0	2.8	1.5
E	S E	S	S	S	S	S E
9 82.7	84.8 83.6	73.2	73.5	72.0	78.6	77.8 81.0
6 11.7	1.3 0.7	5.6	6.3	8.2	6.0	3.8 12.2
3 3.9	4.5 3.6					4.5 5.5
2 1.7	9.4 12.1	21.2	20.2	19.8	15.4	13.9 1.3
807.2	216.7	?	?	?	?	450.0
1 578.2	860.2	1 190.2	2 267.2	2 826.6	346.6	1 385.0
71.5	78	67.4	64.4	68.0	66.5	71.8
28.5	22	32.6	35.6	32.0	33.5	28.2
6 187	3 834	4 063	6 725	10 697	6 860	6 051
5.2	3.8	4.7	6.5	7.7	7.6	5.2
19.0	13.6	...	4.3	0.0	0.6	20.1
75.8	82.6	95.3	9.2	92.3	91.8	74.7
9 679	4 490	4 478	8 156	9 928	1 212	9 461
4.3	4.1	92.8	93.5	94.4	91.3	95.0
88.3	86.4					
7.4	9.5	7.2	6.5	5.6	8.7	5.0

TABLE III. —

—	—	No. 3	5	23	25
Receipts (V + S)					
3-1. Passenger traffic :	Millions of the currency of the country.				
Total receipts.		873.338	729.5	481.25	394.95
1st-class	%	0.8	2.4	6.2	8.0
2nd-class.	%	10.7	21.0	26.4	23.1
3rd-class.	%	88.5	76.6	67.4	68.9
3-2. Goods traffic :	Millions of the currency of the country.				
Total receipts.		1 667.26	1 663.2	1 357.89	1 481.5
parcels and express . .	%	5.5	3.4	25.5	11.5
slow goods	%	94.5	96.6	74.5	88.5
3-3. Total receipts :	Millions of the currency of the country.				
		2 934.32	2 452.0	1 933.3	1 953.9
Passenger traffic + goods traffic.	%	2 556.32	2 400.4	1 849.5	1 883.9
passenger traffic . . .	%	34.5	30.7	26 4	21.3
goods traffic	%	65.5	69.3	73.6	78.7
Expenditure (V + S)					
3-4. Total operating expenditure :	Millions of the currency of the country.	3 001 1	2 620.5	2 263.7	1 949.4
Headquarters		— —	16.3	9.9	1.6
Operating	%	40.9	20.3	30.8	32.7
Way and works	%	27.8	14.2	18.1	15.2
Locomotives and rolling stock	%	31.3	35.4	40.6	50.5
Various	%	...	13.8	0.6	—
Proportion of staff expenditure	%	70.9	63.0	61.2	67.1
For salaries, wages, etc., not including expenditure on social work.	%	52.8	46.4	40.8	54.0
Capital account (V + S)	Millions of the currency of the country.				
3-6. First costs :		26 254	1 670	10 559	7 936
Including for vehicles. . .	%	24.6	22.2	34.4	41.2
4-1. Staff (V+S).					
Total	Heads.	600 595	85 429	81 836	71 456
Administration (headquarters and districts) . . .	%	5.8	4.5	6.1	10.4
Maintenance and supervision of permanent way . . .	%	22.1	21.7	20.6	14.2
Station and goods services.	%	33.4	35.2	31.4	28.1
Train service	%	6.7	5.0	7.1	11.5
Locomotive running (excluding workshops)	%	10.0	9.6	9.8	7 9
Workshops and accessory services	%	22.0	24.0	25.0	27.9

aracteristics.

26	27	28	29	30	31	36
739.4	423.7	7.59	11.46	17.82	12.32	1 135 8
11.3	7.5	7.3	9.8	10.3	11 1	8.4
25.9	18.7	—	4.5	0.0	2.1	26.8
62.8	73.8	92.7	85.7	89.7	86.8	64.8
2 482.7	1 262.9	13.78	26.48	33.73	4.91	1 833 4
21.4	21.5	Not given separately.				18.8
75.6	78.5					81.2
3 325.8	1 745.6	24.51	42.65	58.91	19.67	3 345.9
3 245.9	1 697.6	24.31	42.27	57.93	19.45	3 004.4
23.5	25.4	43.4	37.4	41.8	75.0	39.0
76.5	74 6	56.6	62.6	58.2	25.0	61.0
3 390.3	1 618.0	20.49	35 63	49 14	16.01	3 218.5
11.1	11.0	4.3	3.4	4.1	4 5	1.9
29.6	29.3	35.0	35 4	36.4	31.3	25.8
17.5	18.2	14.3	13.1	13.2	18.5	16.8
41.2	40.3	39.8	43.4	40.7	39.4	35.7
0.6	1.2	6.6	4.7	5.6	6.3	19.8
57.0	67.1	No data.				59.5
47.0	58.2					47.7
18 404	9 181	181.08	349.4	453.04	163.14	39 254
27.4	27.4	11.65	13.4	13.2	10.6	16.1
13 496	56 968	103 839	173 957	224 828	224 839	144 472
6.8	8.9	7.1	7.95	7.7	13.9	10.0
18.4	20.7	15.4	14.3	14.3	22 7	18.1
34.9	30.2	29.8	31.15	32.7	23.6	31.0
8.7	7.2	3.45	3.4	3.6	3.0	10.8
8.8	8.0	14.85	15.1	15.4	12.5	13.9
22.4	25.0	29.4	28.1	26.1	24.3	16.2

TABLE IV. —

—	—	No. 3	5	23	25
Use of the equipment for service purposes.					
Use of the railway 2-1 : 1-1					
Train-km. : length of the lines	km./km.	11 550	13 500	8 080	14 600
Train-km. : length of the running tracks	km./km.	7 950	8 360	5 500	8 650
Use of the vehicles 2-1 : 1-2 (total distance covered : total stock) :					
Steam locomotives (excluding shunting)	...	28 500	18 500	20 200	22 600
Electric locomotives (excluding shunting)	annual km. per vehicle.	40 000	— —	13 700	— —
Railcars	...	31 800	— —	36 000	32 500
Passenger coaches	...	36 600	?	36 500	46 500
Goods wagons (loaded + empty)	...	10 150	?	11 100	11 050
Use of the trains :					
Number of vehicles in a train, excluding brake vans passenger trains	Number of vehicles.	5.83	?	5.51	7.65
goods trains	"	33.2	?	38.0	42.0
Use of the vehicles for traffic purposes.					
1 *locom.* has hauled on the average :					
in passenger trains	Passengers.	73.9	115 5	112.2	122.6
in goods trains	Useful load, tons.	233	259	148	309
Passenger coaches :					
Passengers per axle (traffic) : seats per axle (capacity)	%	22.1	?	37.5	27.4
Goods wagons :					
Useful load of loaded wagon : tonnage	%	60.7	?	31.3	57.7
Average distance carried (V+S) :					
1st-class passengers	km.	365.0	60.1	19.0	94.0
2nd-class passengers	"	31.4	40.9	17.9	71.5
3rd-class passengers	"	23.0	26.0	31.9	23.3
Goods :					
Parcels and express	km.	120	?	224	157
Slow goods	"	161	82	109	129
Service goods	"	144	?	97.5	67 5

Note. — ? = not stated; — — = nil.

es.

26	27	28	29	30	31	36
1 600	8 220	16 400	16 000	20 600	28 400	8 250
7 500	5 700	9 600	8 900	10 550	14 900	6 540
2 400	24 300	28 000	24 200	28 400	34 200	22 900
7 900	34 800	— —	— —	— —	— —	31 400
7 000	47 200	34 400	34 800	37 900	34 600	35 200
9 000	52 800	?	?	?	?	55 300
1 500	15 000	14 650	8 850	10 200	10 250	9 700
10.4	5.23	?	?	?	?	4.98
45.5	43.80	33.6	35.8	34.4	30.3	33.40
79.8	92.1	63.9	66.6	73.3	78.1	65.8
278	225	126	129	120	105	226
13.8	28.6	...	?	?	?	22.4
52.0	40.0	50	45	48.4	48.7	47
262	207	51.8	32.8	46.4	34	207
168.5	131	— —	12.6	4.6	117	131
53.4	48.1	26.4	24.7	25.2	20 9	48.1
308	154	66.5	60.6	78.3	67.5	241
245	186					
113	145	95	87.8	78.0	68.7	92.5

TABLE V.

—	—	No. 3	5	23	25
Use of the staff :					
for track supervision and maintenance :					
per km. of running road . .	Number of staff.	1.71	2.37	2.0	3.1
per million of vehicle-km. .	»	15	?	21.4	16.5
for train working :					
per million of train-km. . .	»	65.6	66.1	82.4	101.0
per million of vehicle-km. .	»	4.8	?	4.9	4.7
for locomotive running (excluding workshops) :					
per million of km. covered by steam and electric locom. and railcars, including shunting	»	74.9	92.5	89.1	107.0
Receipts.					
Ratio of operating receipts to capital cost.	%	11	14.6	18.2	24.7
Operating receipts :					
passenger traffic *(a)*. . . .	per vehicle-km. in the currency of the country.	0.364	?	1.885	1.63
goods traffic *(b)*		0.265	...	1.475	1.53
a : *b*	%	137.5	?	128	107

Note. — ? = data missing.

Notes on the tables :

For the « *characteristics* » :

2-1. Distances covered by locomotives.

The distances run by the locomotives in the different classes of service are shown separately for steam traction (S), and electric traction (E) where the latter is of some importance. It is interesting to compare S and E with one another taking into account the ratios of the distances covered by passenger and goods train (this information is given in 2-1).

3-4. Total operating expenditure.

In comparing the expenses of the different departments, it should be noted that their spheres of action are not everywhere exactly the same, especially as regards headquarters. For this reason, we have calculated separately the proportional values for all the staff expenditure, with and without the expenditure on social work.

ues.

26	27	28	29	30	31	36
2.6	1.53	3.0	2.93	3.44	2.42	2.12
16.6	16.0	?	?	?	?	10.1
86.0	66.1	36.2	36.0	35.0	22.2	116.5
4.1	3.9	?	?	?	?	3.54
70.8	60.8	114.5	118	111	73.3	118.5
18.1	19	13.2	12.2	12.9	12.0	8.55
0.915	1.95	?	?	?	?	2.52
1.575	1.47	?	?	?	?	1.35
58.1	134.5	?	?	?	?	189.5

3-6. First cost.

Sufficiently accurate and comparable information is only available as regards « Vehicles ».

* * *

For the « *values* » :

Use in service.

Passenger carriages.

The number of places available for the traffic, i.e. the kilometre-seats really run, are not known. To replace them, we have used the number of seats per pair of wheels, based on the average stock, viz :

$$\frac{\text{Passenger-km.}}{\text{Axle-km.}} : \frac{\text{Number of seats}}{\text{Number of axles}}$$

of the stock, i.e.

$$\frac{\text{Passengers per axle (in service)}}{\text{Seats per axle (total number)}}.$$

This supposes that the coaches in service correspond in their average composition, to the stock; the question of knowing to what extent this is so depends on the nature of the traffic during the peak periods (Sundays and holidays,

political holidays and others). But, if the use of the vehicles *in service* is not accurately known, the use in service of the *available* coaches and seats is exact.

Goods wagons :

Here again the nature of the wagons supplied is not known, i.e. their tonnage. It has therefore been necessary to compare the average tonnage of the whole of the stock.

The ratio — useful load : weight per axle — represents the use in service approximately, and the use of the stock accurately.

(But, as was said in the text, it is not possible to determine the user *at different periods).*

Receipts.

The economic result is seen by the ratio of the expenditure to the receipts (operating ratio); it cannot be given separately for the passenger traffic and the goods traffic, because the expenditure on each of these traffics is not known. We have decided not to deal with the operating ratio.

Outside the *ratio of the receipts to the capital cost,* we have endeavoured to relate the results (the receipts) to the *service rendered;* in this case the passenger traffic and the goods traffic can be considered separately.

For the comparisons the vehicle-kilometre has to be used as the relative value, because it is the only one which forms a common denominator.

The receipts per vehicle-kilometre in passenger traffic and goods traffic do not lend themselves to any consideration of the classes of traffic; their ratio, however, can be used for comparing different railways, and it shows what should be the *expenditure* per vehicle-kilometre in passenger traffic and in goods traffic for, in each case, the *expenditure to be covered in the same proportion* by the receipts.

Final considerations.

The above study shows that there are many gaps to be filled and that the whole of the possibilities of the international statistics have not yet been brought to light.

It is evident, however, even now, that the development in the use of statistics should start from proportional values of practical utility as regards comparisons in the administrative, operating, and traffic fields, as well as in the financial position, i.e., those comparisons that show the efficiency and the use in the different fields. By this examination, it can be appreciated what numerical data are still missing.

In countries such as France, England, and America, where there are several Railway Administrations, comparisons of this kind are naturally of special importance : such comparisons can be made at the present time provided that the statistics of the Companies of these countries are compiled on uniform bases, as in the case of the English Railways.

[621. 132.8]

Coal-fired railcars,

by Professor H. NORDMANN, V.D.I., Direktor bei der Reichsbahn, Berlin.

(Zeitschrift des Vereines Deutscher Ingenieure — V.D.I.)

Up to the present time, most long-distance railcars have been driven by oil engines. When endeavouring to use national products, one is led — ignoring any petrol produced in Germany — to the use of oil distilled from coal, or coal itself. With a view to encouraging the extension of the use of coal, the Rhenish Westphalian Coal Syndicate offered a prize in 1935. The results of the competition were remarkable and showed that a grate-fired railcar was perfectly practicable, especially if the best features of the designs awarded prizes were combined.

Evolution of the railcar.

Pre-war railcars.

The railcar is much older than is generally realised. Without referring to the earlier and less orthodox suggestions, two Belgian railcars were exhibited at the 1878 Paris Universal Exhibition under the name of « Steam omnibus ». The *Belpaire* car was carried on three pairs of wheels of which one pair were driving, and the *Rowan* car had two four-wheeled bogies, one, the driving bogie, being fitted with coupling rods.

At the time they were built, these railcars could only be steam-propelled, and they also had to be coal-fired (manually); *Belpaire* used a small locomotive boiler arranged across the frame, and *Rowan* a vertical tubular boiler. Early in the 1 880's the German *Thomas* car was introduced; this car was also fitted with a boiler across the frame and the body was a double decker. These cars were intended for working light traffic a full train would have cost too much to work.

The part played by railcars steadily increased, without their purpose changing very much subsequently. They were used on secondary and main lines to run between the usual trains and to act as feeders. However the steam vehicles, especially in Prussia, were gradually replaced by accumulator cars and, just before the war, by internal-combustion-engined vehicles (some with electric drive).

The tendency in steam railcar design was to use better designed boiler, taking little room, but with little or no steam reserve capacity, as for example the *Stoltz* or *Serpollet* (1) systems. Later in South Germany the *Kittel* boiler with steam accumulator was introduced, but the large Bavarian railcars were fitted with small locomotive boilers with semi-automatic inclined grates.

Post-war railcars.

The development of the railcar after the world war continued to progress more particularly in the form of small internal-combustion-engined cars with mechanical or hydraulic transmission. Then the diesel engine gradually took the place of the petrol engine. Railcars on four pairs of wheels were exhibited at the Seddin Railway Exhibition of 1924; it should be noted that the Saxon State Railways used a diesel-engined 8-wheeled railcar as early as 1915.

The high state of development of the diesel engine having made it feasible to apply this engine to main-line railcars, the « Flying Hamburger », of the Reichsbahn, opened the field of the very high speeds over main lines to the diesel railcar (2). The *Kruckenberg* Zeppelin-shaped railcar, not being suitable for a regular service, can only be considered as a

(1) W. Schultes, Z.V.D.I., Vol. 79 (1935), p. 470.

(2) M. Breuer, Z. V.D.I., Vol. 79 (1935), p. 1111.

stage in a historical review of the railcar, however meritorious it may be.

The very high-speed three-phase railcars of the « Studiengesellschaft für elektrische Schnellbahnen » (3) and the very high-speed Bavarian steam locomotive were 30 years in advance of their time.

During the impressive development of the diesel railcar, the steam car had not disappeared from view. In England and in countries following English technical practice, the *Sentinel* (4) steam car is used on a large scale. In Germany, ignoring the small old steam railcars in use in the southern States, the experience with the old internal-combustion-engined railcars has brought out two important advantages of steam units fitted with link gear, namely the ease with which they can be adapted to the load without any intermediate transmission. Transmission with wide steps (with gear wheels as on automobiles) fitted in internal-combustion-engined railcars give a tractive effort in steps instead of a continuous hyperbola with a less satisfactory start for the same nominal power, or the engine has to be excessively large. For this reason the *Doble* type, designed for use on automobiles as well, was given a favourable welcome (5). It consists of a number of high-speed reversible engines suitable for individual axle drive, which are economical thanks to the high steam pressure in conjunction with a tubular boiler without accumulator, occupying little room, in which the steam production is automatically adjusted to suit the consumption as controlled by the driver. The trials of the *Doble* railcars belonging to the Reichsbahn and the Lübeck Büchen Railway have only recently been made; the latter Company has put an eight-wheeled railcar, with two independently driven axles, into regular service.

The Doble boiler, however, is still oil-fired. As there is no steam accumulator, rapid phases of the valve gears of a steam engine when running require an equally rapid succession in the steam produced; an ingenious automatic device starts and stops an oil burner very quickly. With this burner gas oil has been found to give the best results so far; tar oil cannot so far be thought of for such a service.

The competition.

As in recent years great stress has been laid on the use of national constructional materials and fuels, the natural course is to build *coal-fired steam railcars,* in order to eliminate the use of gas oil, most of which is imported. Then too, when oil is used as a fuel, it seems simpler to keep the diesel, as it is more efficient from a heat efficiency point of view, and is now very highly developed, even though a transmission gear is involved.

The Rhenish Westphalian Syndicate, the principal representative of the German coal industry, only carried the above arguments to their logical conclusion by endeavouring to design a steam railcar, and at the end of 1934 announced a competition for burning Westphalian smalls directly on the boiler grate. Naturally this did not mean a return to the steam car of past years, but the adaptation of the steam railcar to the present high standard of railcar design.

Conditions of the competition.

The object of the competition was the design of a three-body main-line railcar seating 180 second-class and third-class passengers, the latter the majority, and capable of a maximum speed of 130 km. (80.8 miles) an hour on the level. This speed had to be reached with an initial acceleration of 0.4 m. (1.32′) per sec. per sec. and a final acceleration of 0.1 m. (0.33′) per sec. per sec. The steam production had to be regulated automatically by the consumption, and for six hours without interruption. Finally the car had to be arranged for driving from either end.

(3) Z. V.D.I., Vol. 47 (1903), p. 903, and Vol. 48 (1904), p. 1086.

(4) (5) K. Imfeld & R. Roosen, Z. V.D.I., Vol. 78 (1934), p. 65.

Designs submitted.

At the end of the 6 months allowed, 20 designs representing very different ideas were submitted. Some of the solutions showed that they could not have been the product of a single mind, but were in fact the result of collaboration between a locomotive builder and a rolling stock manufacturer. The schemes presented by competitors who had worked alone or who had collaborated with other designers on a less extensive scale incorporated certain good solutions of essential questions, but also many failures. Some of the competitors showed a quite unbelievable lack of comprehension of the starting problem or, in other words, of the calculation of the power required. One of them, starting from the use of a turbine and an unnecessary electric transmission, went so far as to calculate with meticulous accuracy the electrical part, instead of the boiler, obviously the essential feature. Other designs put forward overlooked the requirement that a grate must be used. One design involved the use of pulverised fuel with a pulveriser on the car; this method naturally was not acceptable even though the flame of pulverised coal is much more easily regulated than an incandescent bed of fuel on a grate.

For the same reason, gas firing, with gas from a producer, was ruled out. A scheme was turned down although coal firing on a grate was provided. In this case, instead of entirely automatic control, hand firing was proposed. This solution was rather an elegant one as it endeavoured to show that the cost of automatic control with all the auxiliaries involved was about as high as hand firing with a fireman. Finally a solution using a small locomotive of a special design working three carriages was also turned down. This proposal was not for a triple articulated unit, although the idea of being able to repair the mechanical part separately was within the scope of the question. A better solution, the Henschel-Wegmann (6) steam train, was already known.

The schemes turned down, either as unsuitable as a whole or not complying with the conditions, numbered 15, i.e. the majority of the proposals, but numerically only, as the 5 solutions to be examined more closely were those mentioned above which had studied all the details very thoroughly and on more or less uniform lines. When the rejected schemes contained good ideas, consolation prizes were awarded.

Procedure for examining the proposals.

In order to determine the value of the five proposals retained, the detailed questions had to be dealt with, and this was done at the second meeting of the Jury. In view of the condition of burning the coal on a grate, the first thing that had to be done was to see that the proposed grate and combustion chamber were suitable for burning Ruhr smalls. The boiler itself, with its auxiliaries and its control and regulation also had to be considered. All the schemes incorporated condensing at atmospheric pressure in order to avoid carrying too much water and thereby saving room and weight, and to prevent scale forming in the boiler water tubes, the condenser and the precautions taken to keep oil off the heating surfaces had to be examined. The engines too had to be considered as regards construction and power, and as regards accelerative capacity which, in one design, was assisted by steam accumulators of suitable size. The design of the vehicle had to be considered as on it depended the weight and the volume — compartments and engine room — and the traffic capacity. A number of points were also allotted to the use of details which had been tried out in service, as this question might have a specially stimulating effect on the proper design of railcars, besides justifying the reserve

(6) Fr. Boden, Z. V.D.I., Vol. 79 (1935), p. 1467, and especially p. 1470.

expressed by many builders on untried innovations.

It was originally proposed to award a first prize of 25 000 Rm. and five other prizes of 5 000 Rm., but this presupposed that the best scheme was so markedly better than the others as to justify the difference between the first and second prizes. This was not so, however, as the above mentioned factors of the general scheme were not all found in what was considered the best form in the same solution. After awarding 5 000 Rm. as consolation prizes for the individual ideas, the Jury decided to distribute the awards as follows : 15 000 Rm. to the best solution, 10 000 Rm. to the second, 7 500 Rm. to the third and fourth, and 5 000 Rm. to the fifth (7).

The report on the competition therefore cannot be a description of the solution deemed to be the best because it obtained the highest number of points, but must discuss the various important points.

The prize schemes.

Grate and combustion chamber.

The largest number of points was naturally given to the grate and combustion chamber. The Jury considered that the design which could be regulated the best, and at the same time was suitable for burning Westphalian smalls, was a rocking grate in sections with blower jet below it. This arrangement was incorporated in the M.A.N. design in conjunction with a large enough combustion chamber for the tubes to remain free from deposits of soot and tar. Neither another moving grate inferior in design, nor a cooled mechanical grate, nor again an arrangement for projecting the fuel unto the grate were considered as deserving as regards control and durability, although a large enough combustion chamber was provided in several schemes.

Boiler.

With one exception, the boilers were all high pressure. The prize schemes all incorporated forced circulation or forced flow, as taking less room and being lighter. The Henschel scheme simply included the Doble boiler, the coil of which was placed, not round the burners, but around and above the grate. The best solution undoubtedly was Krupp's (figs. 1 and 2). On the water side, it is very adaptable to working conditions, as any excess of heat on the grate is used to feed a steam accumulator of sufficient capacity to deal with most of the work done in acceleration, and yet is small enough not to increase the weight of the vehicle excessively. This adaptability on the water side is very attractive as the fire is undoubtedly more difficult to regulate than with oil firing. When the grate is stopped and the rate of firing reduced, there is always a considerable amount of heat radiated from the bed of incandescent fuel. To prevent any loss of pure water through the safety valves lifting suddenly, the steam must pass to the condenser which must then be made larger unless, as when an accumulator is provided, there is little danger of this happening.

Auxiliary machinery.

As the working had to be automatic,

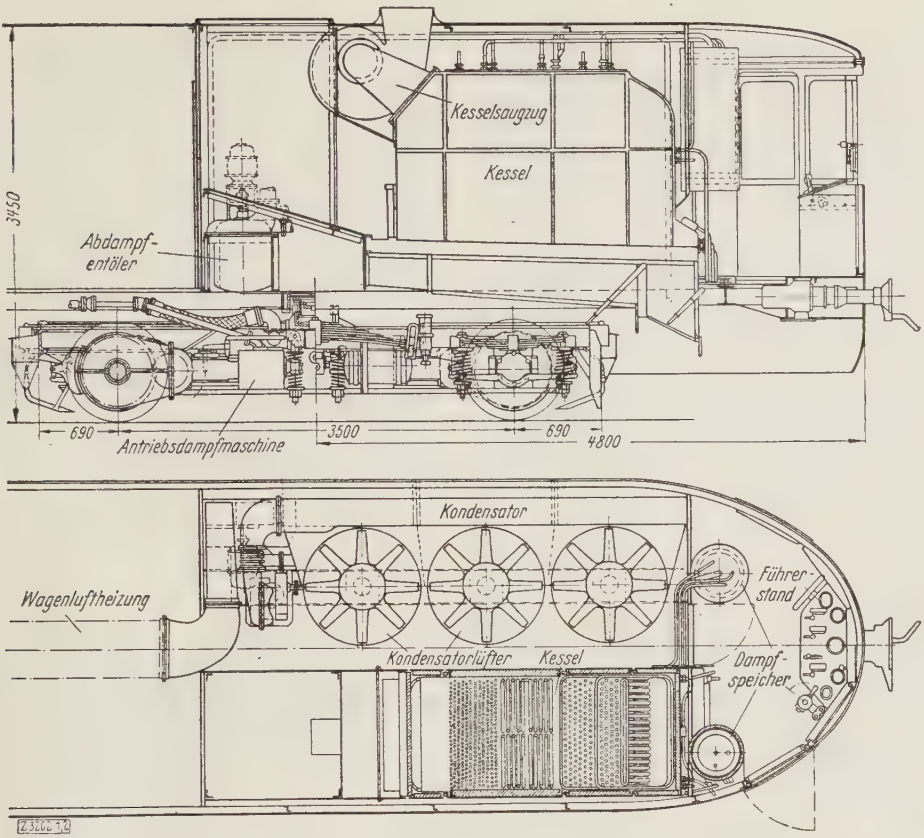
(7) 1st prize : Fried. Krupp A.-G., Essen, in collaboration with Vereinigte Westdeutsche Waggonfabriken, A.-G., Cologne-Deutz (abbreviated to Krupp in this article).

2nd prize : Maschinenfabrik Augsburg-Nürnberg Werk, Nuremberg, in collaboration with Herr DEHM, Engineer, Reichsbahnbaumeister, Munich (designated as M.A.N. hereafter).

3rd prize : A. Borsig Maschinenbau, A.-G., Berlin-Tegel, in collaboration with Christoph & Unmack, Niesky (Lausitz) (abbreviated to Borsig).

4th prize : Henschel & Sohn, A.-G., Cassel, in collaboration with Waggonfabrik Gebr. Crede (abbreviated to Henschel).

5th prize : Rudolf HENNIG, Engineer, Castrop-Rauxel in collaboration with Waggonfabrik Ürdingen, A.-G., Ürdingen, and Heinrich STEYMANN, Engineer, Ratingen (abbreviated to Ürdingen).



Figs. 1 and 2. — Mechanical equipment of the Krupp scheme. Propulsion : two three-cylinder steam engines, each driving one axle through gears.

Explanation of German terms:

Kesselsaugzug = boiler aspirator. — Kessel = boiler. — Abdampfentöler = exhaust steam de-oiler. — Antriebsdampfmaschine = steam engine. — Wagenluftheizung = hot air heating of the coaches. — Kondensatorlufter = condenser cooling fan. — Führerstand = driver's stand. — Dampfspeicher = steam accumulator.

the auxiliaries and their adjustment were also an important factor in judging the designs. As there was no direct exhaust, *a blower had to be used to draw up the fire, the action of which blower depended, like with mechanical firing of the grate,* upon the quantity of steam required. The third detail to be considered was the *feed pump,* and finally the *fan for cooling the condenser.* In certain special cases the admission of steam to the collector or from the collector or the auxiliary pipes through which the exhaust gases pass, had to be regulated. As has been seen there are many factors of varying nature and importance to be taken into account. The start is generally given by thermostats and pressure regulators as in the Doble boiler, the method of adjustment of which we will describe in a few words. An excessively high superheat temperature or boiler pressure stops the blower on the oil burner; when the temperature drops excessively the

blower and then the feed pump are restarted.

The *condensers* showed the least variations in their theoretical design; the Krupp feed was considered the best, owing to the ability with which the dimensions had been selected and the way the cooling air was taken in.

The M.A.N. scheme was thought to include the best solution as regards the auxiliaries, seeing that the electrical operation of all the auxiliaries formed at the same time an electric control; besides it was thought that it would be advantageous as regards the efficiency of the main engine, that the current generator was not driven by a free exhaust steam turbine, but by a turbine with live steam, so that the main engine uses all the time the drop of pressure to the condenser (fig. 3). Three designs used exhaust steam turbines for the auxiliary engines as in the Doble design; as on the one hand the latter had shown its good points in service, and as the back pressure of the turbine had lost of its importance with high boiler pressures, it was not necessary, in the calculations, to descend much below the maximum number of points.

Feed water.

Considerable importance was attributed to the question of the feed water because the heat transfer surfaces free of solid or greasy deposits give a better guarantee against power losses, or at least entail least maintenance costs. Here

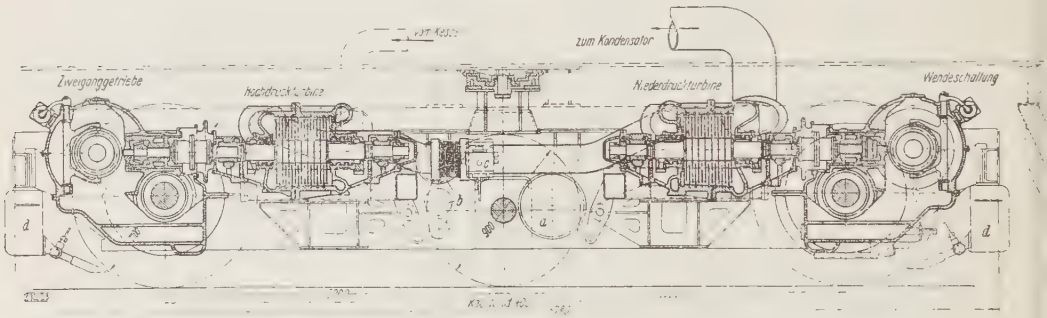


Fig. 3. — M.A.N. six-wheeled driving bogie.

Propulsion : two steam turbines driving the two outer pairs of wheels through two-speed gears and jack shafts. — *a*, Compressed air reservoir for the brake. — *b*, Auxiliary air reservoir. — *c*, Brake operating valve. — *d*, Sander.

Explanation of German terms:

Vom Kessel = from boiler. — Zum Kondensator = to the condenser. — Zweigangetriebe = two-speed gear. — Hochdruckturbine = high-pressure turbine. — Niederdruckturbine = low-pressure turbine. — Radstand = wheelbase.

the M.A.N. design using turbines as the main engines, stood first; this selection was inspired directly by the wish to avoid oil deposits on the heating surfaces and cooling surfaces. If the amount of cleaning to be done is taken into account, in face of the results obtained in service with the Doble piston engines of the Lübeck-Büchen Railway, it was also necessary to take into account schemes providing for oil separators of medium efficiency, whereas two schemes which had failed in part or completely to consider the presence of oil in the exhaust steam and its action on the heat transfer surfaces of the boiler received no points under this heading.

Main engines.

For the main engines, the Doble type

was mostly preferred by competitors; this is a high-speed compound, horizontal and reversible engine, so as to drive individually some of the bogie wheels through a gear. In two cases the real Doble form, i. e. the two cylinder compound engine, was chosen. Krupp had a variant with three cylinders which could be operated as triple expansion to give a high starting torque, which for these reasons got more marks (figs. 1 and 2).

The M.A.N. solution, though classed lower down, nonetheless deserves to be mentioned as being very interesting. The original proposal in this case was also to use high-pressure high-speed piston engines, but the fear of oil getting on the heating surfaces led to the use of turbines (fig. 3). As the powers to be developed are small for turbines, in order to reduce the blade losses to a reasonable figure a boiler pressure of 12.5 kgr./cm² (178 lb. per sq. in.) was selected; this necessarily resulted in a low efficiency of the (ideal) turbine, which with its atmospheric condensation, remains outside the fruitful range of vacua. Each of the 6-wheeled bogies was to have two pairs of wheels driven by the turbine, one at high pressure and one at low pressure; as the ratio of the maximum starting power to the working power of the railcar is as 2 : 1, one pair of turbines had to be cut out as soon as the working speed had been reached. In order not to work under too unfavourable conditions at low numbers of revolutions, a double reversible transmission by which two speeds could be obtained was to be used, so that the turbines, ignoring the first starting moment (speed = 0) had not to change their number of revolutions between too wide limits. This is undoubtedly an ingenious, but complicated solution.

Whilst taking into account the constructional principle consisting in arranging the engine under the floor as far as possible, the fifth scheme embodied a vertical steam engine which projected through the floor, thus reducing the useful area of the latter; moreover, owing to its regulation by throttling instead of by expansion, this scheme appeared so uneconomical that the Jury classed it at the end of the prize schemes.

Calculation of the mechanical part.

As regards the calculation of the mechanical part, the two conditions set forth in the wording — working speed, 130 km. (80.8 miles) per hour, immediately preceded by an acceleration of 0.1 m. (0.33′) per sec. per sec., and starting acceleration of 0.4 m. (1.32′) per sec. per sec. do not supply given values, because the vehicle weight and the streamlined shape of the ends have to be taken into consideration. However, with the actual shape of the ends of railcars and a weight of about 120 t. (118 Engl. tons), the power at the working speed may be taken as about 500 H. P., and the accelerative power (above the limit of adhesion of the driving wheels) as about 1 000 to 1 200 H. P. This was about the power given in four of the five schemes, the specific power given in the Krupp design being the most favourable one. The M.A.N. scheme, with 1 800 H. P., to which corresponds, it is true, a weight of 94.8 t. (93.5 Engl. tons), for the power vehicle alone, is undeniably based on excessive assumptions.

As regards the *accelerative* capacity, the Krupp scheme is again the best, seeing that the acceleration work can be done by the steam accumulator, and that the boiler control operations are reduced to a minimum, because the boiler output can be almost constant. As the acceleration can still be effected by means of a moderate specific boiler output, the condition relating to the acceleration can still be improved by means of an increased boiler output, or else excess power remains available for gradient climbing, so that this scheme comes first as regards specific power.

General construction of the railcar.

The Krupp design, however, does not retain this great advance, if the construction of the railcar is considered as a whole, though it obtained the greatest number of points. Just as with the Henschel and Ürdingen designs, provision is made at each end of the three-unit railcar for a boiler and an engine developing half the nominal power. In this way the passenger compartments are all grouped together, and the riding is good, thanks to the absence of pushed vehicles. If need be, if one of the engines developing half of the power fails, the other can still drive slowly, and, as the case may be, push the train. With this arrangement, only small advantages relatively to the accessibility justified one of the schemes of the same kind being given a better place.

The two other solutions only provided for a single power unit, placed either at one end or in the middle of the train. In the first case, the condition of the passenger compartments following one another without interruption (rapid occupation of the seats in the case of heavy traffic) is still fulfilled and fuel need only be provided at a single place — which is even a slight advantage — but two vehicles have to be pushed in one running direction, which appears to be somewhat risky at 130 km. (80.8 miles) an hour. The reserve of half the power of the engine is lacking. The power vehicle with a post office compartment, located in the middle of the last scheme, does not satisfy the primary condition of continuity of the passenger compartments, so that it had to be placed at the end of the list, although pushing one coach, in each direction it is true, appears more acceptable than pushing two.

As regards the purely constructional part, no differences could be observed.

Use of proved constructional details.

As the use of constructional parts of proved design was to give a feeling of security for the proposed construction, and as consequently the authors of the schemes may have hesitated to choose very daring methods of construction, in this case also, as stated above, a certain number of points was laid down for the appreciation of the solutions put forward. In this connection, there is no doubt that Messrs. Henschel, who built several large Doble railcars in Germany, had the advantage over the other competitors, in a scheme which used to a large extent the principles of the Doble design.

The above review of the guiding principles the Jury kept in mind shows that the best scheme does not now represent the integral sum of the best individual elements. In making this remark, we do not in any way wish to depreciate the merit; had any scheme had to be selected or rejected as a whole, the « Ruhrgold » (name of the Krupp design) would certainly have been chosen. Small improvements would be possible, however, by combining its original form with some details of construction from other designs, for example by applying the moving grate to the combustion chamber which, moreover, lends itself well to this modification. For this reason, the Rhenish-Westphalian Coal Syndicate submitted to the Reichsbahn Headquarters the results of the competition, expressing the desire that the practical utilisation of the proposals awarded a prize should be investigated.

In our opinion, the principal result obtained is that a certain number of well known builders afforded a proof, by their carefully got out designs, that the grate-fired railcar, in the form of large multiple units for the main lines, can quite well be realised. The experienced engineers naturally also knows that all vehicles with various new details of construction require a certain time to be fully developed. It will now depend on the Management of the Reichsbahn to decide whether they wish to adapt themselves to the initial difficulties inherent in such a large railcar to start with. Whatever the case, we are glad to see that this opens a new outlet to the national fuel.

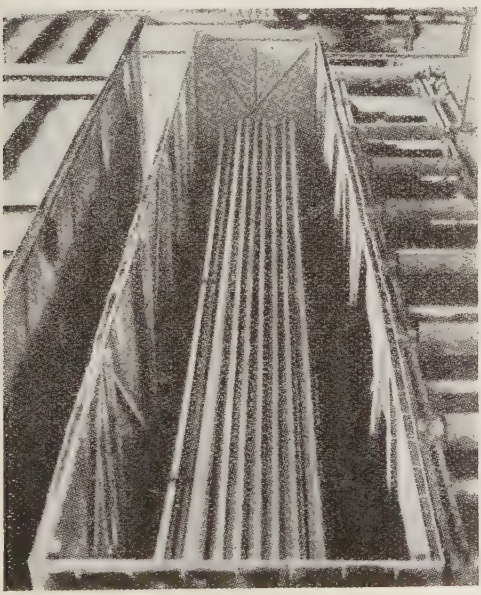
[625 143.2 (.73)]

Recent advances in rail manufacture.

(Railway Age.)

Much thought has been given to transverse fissures. What causes the disease ? What is the cure ? The last word has not yet been said as to the cause, but much has been done in the way of a cure.

Nearly ten years ago, Messrs. Sandberg, of London, England, internationally known rail engineers, pointed out the probable connection between shatter cracks and transverse fissures. According to the Sandbergs, shatter cracks, which occur occasionally in rails as rolled, may act as the foci from which transverse fissures gradually develop within the heads of rails during service. According also to the Sandbergs, « one of the chief causes » of shatter cracks are stresses caused by « a substantial difference of temperature during cooling between the outside metal and the interior metal, more particularly of the big mass in the head of the rail ».



One of the delayed cooling boxes employed in the slow-cooling process of rail manufacture, partly filled with rails.

They believed that if the occurrence of shatter cracks could be prevented, the transverse fissure problem would be solved. Accordingly, they instituted an exhaustive series of experiments in this direction. Before the end of 1928 they had developed a method of controlled cooling at the Cargo Fleet Iron & Steel Works at Middlesbrough, England, which appeared to have effectively prevented the occurrence of shatter cracks. In the succeeding year they introduced this method into the United States, where, after a period of several years' experimentation on the higher carbon American rail by the Bethlehem Steel Company, the process was adopted by Bethlehem on a commercial scale. More recently the method has been adopted by the Inland Steel Company and the Colorado Fuel & Iron Company.

Other investigators, Gerhardt of the Bethlehem Steel Company and Mackie, of the Dominion Steel & Coal Corp., Ltd., of Sydney, Nova Scotia, likewise diagnosed shatter cracks as the principal cause for transverse fissures and, like the Sandbergs, found the cure of shatter cracks in the controlled cooling of rails. At the present time the last mentioned company is subjecting its entire output of rails to controlled cooling.

The ideas and practices of the Sandbergs, Gerhardt and Mackie have been confirmed in essentials by recent scientific investigation. The work, for example, conducted at the University of

Illinois, under the auspices of the Association of American Railroads and the Rail Manufacturers' Technical Committee, is especially significant (1).

In this work at the University of Illinois, equipment was used to subject rails, under laboratory control, to conditions simulating those of actual service and thus to develop transverse fissures in those rails having susceptibility thereto. « Tests of rails under rolling loads » employing this equipment « have yielded fairly convincing evidence that fissures in rails usually originated at shatter cracks which formed in the rails during the process of manufacture. All laboratory-developed fissures were in shatter-cracked rails and about 75 per cent of the service-fissured rails sent to the investigation showed evidence of shatter cracks outside the main fissure. »

From the above mentioned report it also appears that the University of Illinois made comparative tests of hot-bed cooled and controlled-cooled rails from four different mills and that while some of the hot-bed cooled rails had shatter cracks and developed internal fissures when subjected to rolling load tests, none of the controlled cooled rails had shatter cracks or manifested internal fissures when subjected to such tests.

Not all the rails cooled in the usual way on the hot-bed contain shatter cracks. It is known that only a very small percentage of the rails rolled contain shatter cracks, and even in those rails the number of shatter cracks is small. But their occurence is insidious. Shatter cracks are sometimes found in rails produced from a particular ingot of a heat and absent from other ingots of the same heat. A limited portion of a rail is sometimes found to contain a few shatter cracks while the remainder of the rail is entirely free from them. Obviously there can be no real assurance of freedom from shatter cracks unless all rails are subjected to the controlled cooling operation. Without vaccination the majority of human beings might not have small pox, yet universal vaccination is the only sound prophylaxis.

(*) An abstract of the first published report on this investigation was published in the *Railway Age* of August 31, 1935, page 273.

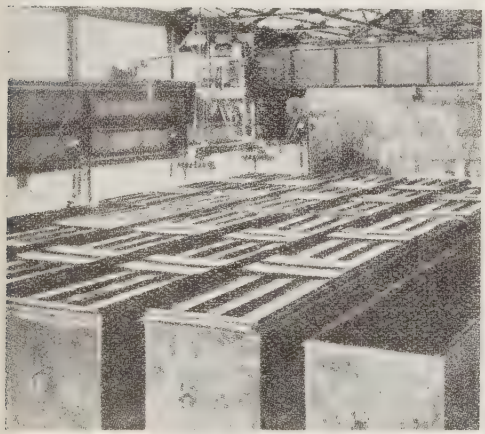
Details of controlled cooling process.

More than five years of experimentation was necessary to determine just the conditions requisite for controlled cooling of American rails, and to develop the process on a commercially effective scale. As applied at the mills of the Bethlehem Steel Company, for example, the practice in its broader aspects may be outlined as follows :

The rails are cooled on the hot bed in the usual manner until the temperature has dropped as low as 1000° F. but not less than 932° F. They are then placed in boxes or tanks for slow cooling, a sufficient number of rails being placed in each box to insure a slow and gradual drop in temperature. After being loaded, the boxes are carefully covered, and the joints are made sufficiently tight to avoid cool currents of air coming into contact with the rails. Moreover the boxes are protected from exposure to snow and rain. The rails remain in the boxes or tanks until their temperature has dropped below 400° F.

Practical experience, as well as extensive laboratory experimentation, has indicated the importance of starting the controlled cooling at a sufficiency elevated temperature, but, of course, below the transformation range, and continuing the retarded cooling to a temperature below 400° F. There has been some difference of opinion among investigators as to within what ranges of temperature, during cooling, rail steel is most susceptible to the formation of shatter cracks. The Sandbergs, for example, inclined to the belief that the tendency to shatter cracks was greater between 932 and 650° F., while Gerhardt and Mackie held the

view that the tendency to shatter cracks was greatest below 650° F. Both the Sandbergs and Gerhardt agreed, however, that in practice it was important to start at a sufficiently elevated temperature to allow a substantial margin of safety. Mackie, in describing an application of his process which was « 100 per cent effective in eliminating all traces of shatter cracks », stated that the rails were allowed to cool normally on the hot-bed until visible redness in a dim light had disappeared, and then were placed in the cooling tank as promptly as practicable.



Covers are placed on the boxes full of rails while they undergo the slow cooling process.

Apart from the prevention of shatter cracks, the controlled cooling substantially reduces the residual stresses in the rails, thereby greatly minimizing the tendency to the development of weaknesses in the rail, other than transverse fissures, during service. The controlled cooled rails show substantially higher results in bend tests than ordinary hot-bed cooled rails. The ductility is better. All these results are obtained without appreciably affecting the hardness of the rail as determined by laboratory tests as well as by measurements of the wear of the rails in track.

The production of controlled-cooled rails in Europe has reached the figure of approximately 1 000 000 tons and the production of such rails in the United States and Canada now aggregates about 385 000 tons.

In the efforts to meet the increasing need for rails of higher physical characteristics, substantial advances have been made through heat treatment. The term « heat treatment » is here used because of its general acceptance in the industry, instead of the more accurate, but also somewhat more cumbersome, expression « quenching and tempering ».

When the demand for rails capable of greater and greater loads first appeared, metallurgists naturally began to consider the feasibility of applying to rails the well known effects of quenching steel in greatly increasing its hardness and strength. Some thirty years ago various methods of heat treating rails began to appear in the technical journals and patents.

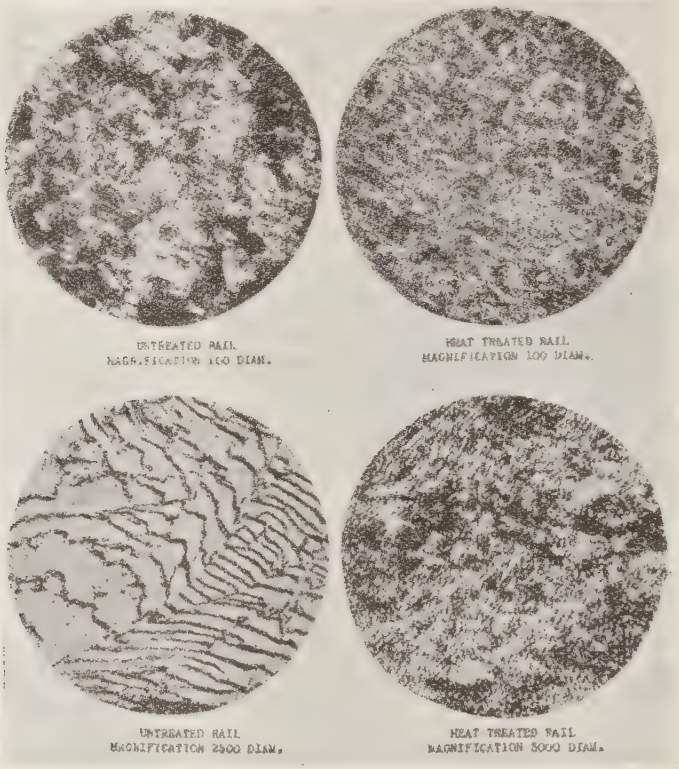
It was soon discovered however, that the problem was simple. The usual methods of heat-treating steel articles could not be successfully applied to rails. A rail offers certain special obstacles to ordinary quenching operations. Its peculiar cross section with its unequal distribution of metal, its great length, the great mass of metal, particularly in the head, and the high carbon content, all contribute to the difficulty of effective, yet safe, quenching.

For years attempts were made to solve the problem, but with indifferent success. All of the ordinary methods developed stresses sufficiently great to cause ruptures in the metal, particulary within the interior of the head.

After a period of experimentation lasting some twenty years, Edward F. Kenney, of the Bethlehem Steel Company, discovered a process of preventing these ruptures, which is described in United States Reissue Patent No. 17 240. The practical embodiment of the Kenney process as it has been practised by the

Bethlehem Steel Company involves quenching the rail while cooling from mill heat, discontinuing the quench at a definite temperature, promptly effecting equalization at an elevated temperature, and finally subjecting the rail to controlled cooling.

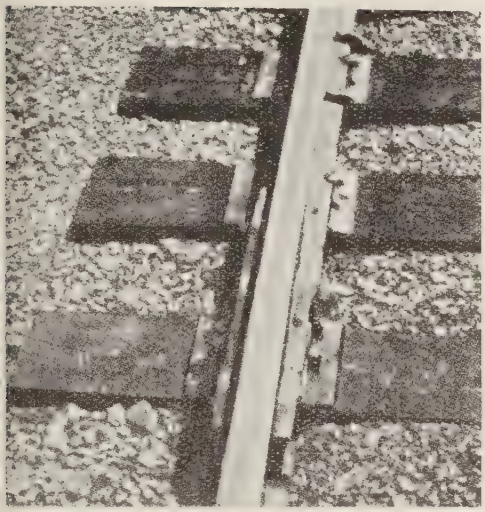
This treatment is exceedingly important. The present trend is decidedly in the direction of higher speeds in train service. Under the higher speeds on tracks today, the dynamic wheel load sometimes exceeds 100 000 lb. At times, nearly all of the enormous axle load on



Photomicrographs showing the structure of the steel in heat-treated and untreated rails.

a pair of wheels is concentrated on a single wheel. The entire braking effect at high speed may be applied on a small area of contact between one wheel and the rail, amounting to only from 1/3 to 1/2 a square inch. Under these concentrated loads the surface metal of the rail tends to flow. This tendency to flow is opposed by the underlying metal, thereby resulting in great tensile stresses within the interior metal. With the high speeds of today the need for high physical characteristics of rails is great; with the prospective, and probable, higher speeds of the near future, the need will be imperative. Heat treatment of rails effectively meets this need.

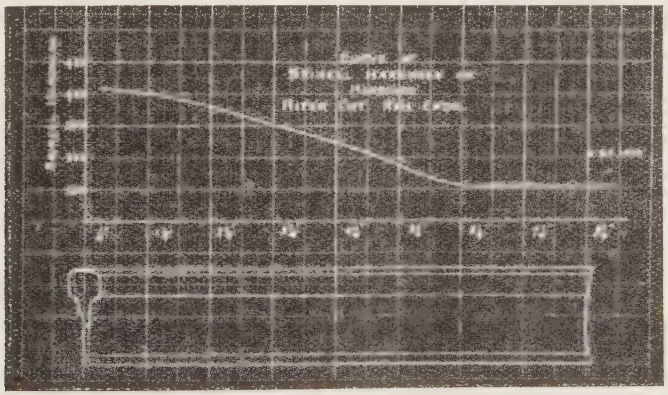
A study of the accompanying table and



Close-up view of mitred rail ends in service at an otherwise ordinary joint.

Close-up view of mitred rail ends at an insulated joint.

photomicrographs, giving the comparative physical properties, and structure of treated and untreated rails, will plainly indicate why the treated rails are far superior in resisting the stresses induced by high train speeds. Kenney's aim was to produce rails in which the elastic limit was sufficiently high to minimize



Curve of Brinell hardness of hardened, mitre-cut rail ends.

greatly or entirely prevent the plastic flow of the outer metal of the rail head due to the concentrated wheel loads. The chart indicates the marked increase in elastic limit due to heat treatment. Not only does the greater elastic limit inhibit the tendency to plastic flow of the outer metal of the rail head, but the high elas-

tic limit of the inner metal enables the steel to resist effectively the tendency of the outer metal to flow.

Moreover, the heat treated rail has a far greater life than that of the untreated rail, due to its increased resistance to wear. According to recent reports from five railroads, the average wear in the high rail of curves when heat treated, was only 54.6 per cent that of the untreated rail, and in the low rail, when heat treated, but 55 per cent of the untreated rail.

Messrs. Sandberg, of England, have developed a special method of heat treating rails involving the application of vaporized water (« Scotch mist ») to the rail head, followed by a controlled cooling. This process is now used by most of the rail making plants in Europe, where, up to March 31 of this year, more than 100 000 tons of rails were produced through the use of this process. While this process has not had general application in this country, its possibilities must not be overlooked.

Rail end batter and its correction.

One of the weakest elements of railway track under modern service conditions is the joint. Long before rails are worn out by the abrasive action of the wheels, the joints have usually become loosened by wear on the contact surface between the rails and the joint bars, particularly under the heads of the rails and the tops of the bars. When the wear has become too great, rails have frequently been taken out of track, the ends cut off to remove badly worn parts, new holes drilled, and new joint bars installed on the shorter length rails. This relatively short life of the rail ends and joint bars is due in most part to the impact of the wheels in passing over the joints, especially where the impact has battered the rail ends to form a depression.

Efforts have been made to correct this battered condition by depositing molten steel to fill in these depressions, followed by grinding to an even surface. It is far cheaper and safer to prevent or minimize this battering than to attempt to correct if after it has occurred. The method most commonly used for accomplishing this, is that of hardening the ends of the rails. Several methods of hardening rail ends are being used at the present time.

Hardening of rail ends.

In one method of hardening rail ends, the top surface of the head in the region at and adjoining the end of a cold rail is brought to a very high temperature by the application of the electric arc or by torch and then subjected to a quenching action by means of water, oil, or air. The most satisfactory method for the hardening of rail ends, not merely from the standpoint of safety, but also from technical and economical considerations, is to quench the end regions while the rails still retain the mill heat. At the mills of the Bethlehem Steel Company, the end regions are treated as the rails lie cooling on the hot-beds. A multiplicity of water jets is applied to the end regions from a portable quenching head, which also protects the remainder of the rail from accidental contact with the water. The period of application of the spray is controlled automatically by electrical timing apparatus. The large reservoir of heat in a full length rail at a red heat and the plasticity of this red hot metal furnish ample assurance against any part of the rail being subjected to severe cooling strains.

Rails thus end-quenched from the mill heat are either subjected to controlled cooling throughout the length or, where the rails thus treated are not to be controlled cooled, a portable annealing cover is applied to each end when it has cooled to approximately 1 000° F. and this cover is retained in place until the rail end has cooled to below 400° F. The degree of hardness and the depth of pe-

Comparison of treated and untreated rail, 130-lb. R. E. rail section.

Heat.	Analysis. Per cent. C.	Mn.	Tensile strength. Lb. per sq. in. Treated.	Untreated.	Elastic limit. Lb. per sq. in. Treated.	Untreated.	Elongation. Per cent. Treated.	Untreated.	Reduction. Per cent. Treated.	Untreated.	Brinell average for head. Treated.	Untreated.	Drop test. Permanent set 1st blow, inches. Treated.	Untreated.
82K253	0.74	0.69	173 500	134 000	124 700	79 000	9.5	7.5	14.5	9.5	347	269	0.57	0.90
83K205	0.72	0.70	185 000	137 800	131 000	83 300	6.5	10.0	9.5	14.2	368	278	0.50	0.85
82K255	0.71	0.68	170 500	135 000	124 500	81 300	7.5	10.5	10.3	14.8	351	274	0 57	0.93
85K246	0.79	0.72	184 500	144 300	123 700	86 500	8.2	8.5	11.8	11.0	356	294	0.55	0.80
84K247	0.78	0.82	182 000	151 000	126 000	89 000	10.0	8.5	15.0	11.5	363	307	0.50	0.80
84K249	0 72	0.72	171 500	137 300	124 700	84 200	9 0	9.5	15 3	13.7	372	290	0.51	0.83
84K250	0.77	0.84	172 500	149 500	126 000	86 500	10.5	8.0	20 5	11.5	375	311	0.52	0.82
85K249	0.76	0.70	184 800	142 500	131 000	86 200	7 5	9.0	13.8	12.7	375	291	0.50	0.85
82K279	0.71	0.63	177 000	133 800	128 500	77 800	7.7	6.5	12.0	9.0	361	277	0.66	0.90
Average	0.74	0.72	177 900	140 600	126 700	83 300	8.5	8.7	13.6	12.0	363	298	0.54	0.86

Izod impact tests : Standard 0.4-in. diameter notched bars—treated, 7 foot-pounds; untreated, 2 foot-pounds.

netration within the head metal are easily controlled.

There are very substantial advantages in end hardening rails from the mill heat and control-cooling the entire rail from 932° F. to below 400° F. This mode of treatment produces a rail having all the advantages set forth above for the controlled-cooled rail plus the added advantage of hardened ends.

Mitred-end rails.

The high train speeds of the present and the future must be accompanied by riding comfort for passengers and reasonable costs in the maintenance of rolling stock and track. The greater the speed the smoother the track must be. An important means to this end is the mitred-end rail.

About thirthy or forty years ago rails were tried out in track having 45-degree angle mitred-end faces, the mitred cut extending the full depth of the rails. So far as giving better riding qualities and reducing batter at the joints they were a success. The movement of the rails, however, relative to one another, produced a wedging action which broke joint bolts and caused such a dangerous track condition that the rails were taken out of track and the idea abandoned.

Later the idea was proposed and carried out of providing a mitred cut through the head and a square cut through the base. This combination avoided the danger of wedging, but in preparing them it was necessary to machine the ends of the rails after they had become cold. This was so expensive that no considerable tonnage was ever installed.

A few years ago a method was devised for producing this combination of square end base and mitred head end quickly and accurately while the rail was still at the mill heat. All rails thus produced are absolutely interchangeable. Tonnages of mitred-end rails thus produced, some hardened and some unhardened,

have been in service up to three years on some of the most important railroads of the United States. They were purposely installed at points of extremely heavy traffic. The batter of the joints has been reduced from 50 to 75 % of that experienced with ordinary square-end rails, and the noise and shock, as the wheels of trains pass over the joints have been decidedly reduced.

In this connection, it may be well to point out that some of the railroads having the heaviest traffic have made long time studies of joint batter. These studies show that of the total batter which occurs in a period of from three to five years, more than half occurs during the first few weeks. The passage of only a few trains is sufficient to batter the corners of the square rail ends and cause a marked blow as the wheel passes over. The mitred joints permit of the load passing gradually from one rail to the next, thus reducing the reversal of shear in the joint bar and protecting the end corners of both rails. Furthermore, a greater degree of hardening is permissable in the mitred-end rails than that which could be given safely to the square-end rails.

One of the accompanying photographs illustrates an installation of mitred joints in the main line of one of the transcontinental railroads. Of particular interest in this picture is the fact that it shows an insulated joint. The mitred joint is of special value under these circumstances. The gradual transmission of the load over the joint is very effective in protecting the insulating fibre.

This article has been confined to certain improvements in rails after they have been given their final form as rolled products. It leaves untouched the manifold advances in steel making and shaping. From the blast furnace to and through the rail mill there has been an increasing application of scientific knowledge for the purpose of controlling and governing the multifarious chemical, metallurgical and thermal factors involved in the manufacture of rails for track service. Metal and slag analyses, mold preparation and use, design and operation of furnaces, temperature control of rolling, and chemical and metallographic checks, all have contributed to the steady advance of rail manufacture. All of this care in preparing good steel and rolling it into a rail should not be vitiated by neglect in the subsequent treatment, thereby lessening its value as a safe and serviceable product for the use of our railroads. Nevertheless it still remains axiomatic that a good rail can be made only from good steel.

[625. 111 (.73) & 625. 162 (.73)]

New York Railroad Club discusses the grade crossing problem.

(Railway Age.)

In a comprehensive program dealing with highway-railway grade crossing protection and elimination, presented before a meeting of the New York Railroad Club on May 15, 1936, five speakers representing both the railways and city and federal highway authorities, discussed at length the problems of grade crossing protection and elimination and the best means of carrying out this large task in the future. The outstanding feature of the meeting was the general recognition and admission on the part of all of the speakers, that in view of changed conditions, the main responsibility for grade crossing protection and separation is no longer the railway's, in view of which there should be a more equitable division of costs for this class of work between the railways and public agencies.

Commissioner sees railway's share too high.

The meeting was opened by C. E. Smith, vice-president of the New York, New Haven & Hartford, and president of the Club, but the program was presided over by Leon G. Godley, a member of the Transit Commission of the City of New York. The speakers included Thomas H. MacDonald, chief of the U. S. Bureau of Public Roads, who spoke on the national aspects of the grade crossing program; Richard E. Dougherty, vice-president of the New York Central System, who outlined the character and scope of the extensive West Side Improvements of the New York Central in New York City; A. H. Rudd, chief signal engineer of the Pennsylvania, who discussed grade crossing protection; Lewis J. Carruthers, general attorney of the Long Island, who pointed out the legal aspects of grade crossing elimination in New York State; and Edward W. Foley, president, Faircroft Engineering Corporation, who illustrated with lantern slides some of the major grade separation projects carried out by his company in the New York Metropolitan area.

In his opening remarks, Mr. Godley, referring to his long connection with the grade crossing problem in New York City, spoke facetiously about the recently changed attitude of railway officers toward him, stating that for years, when the railways were paying the major part of the bills for grade separation, railway officers avoided him like a plague, crossing the street when he approached, while now, with government money available, he is studiously sought out and cultivated.

He offered no criticism in this connection, realizing his constant pressure for grade separation work and the large expenditures imposed on the railways, and, in fact, stated his belief that the proportion of grade crossing elimination costs charged to the railways, usually 50 per cent in New York state, is too high. He said that, in his opinion, which might be incorrect, the railways should be required to pay in each case a sum equal to not more that the capitalized annual expenditure for adequately protecting the grade crossing.

MacDonald praises railroad co-operation.

In brief extemporaneous remarks,

Mr. MacDonald first pointed out that of the $ 200 000 000 grade crossing fund made available by the federal government in 1935, $ 175 000 000 had already been assigned to approved projects. For this progress which he considered rapid in view of the magnitude of the problems presented, be gave credit in large measure to the railways for their co-operation, and, more particularly, acknowledged the « splendid co-operation » on the part of the grade crossing committee of the Association of American Railways. He characterized as « a remarkable example of co-operation » the fact that in all of the negotiations with the railways thus far, there had not been, to his knowledge, a single major dispute.

To emphasize the progress which has been made in grade separation in recent years, Mr. MacDonald pointed out that whereas approximately 6 000 grade crossings were eliminated in the country during the 16 years prior to 1933, a total of approximately 3 000, including the rebuilding of a number of old grade crossing elimination structures, have been eliminated during the three years ending with 1936. He said that in connection with all of the work being done under the $ 200 000 000 federal grant, for both grade crossing elimination and protection, the Bureau of Public Roads had accepted the recommendations and standards of the Association of American Railroads, and its engineering and signaling divisions, the American Railway Engineering Association and the Signal Section. Concerning grade crossing protection, he expressed full accord with the views held by Mr. Rudd, as outlined in his paper presented at the beginning of the program.

Sees further federal aid.

Referring to the future of grade crossing work, particularly from the standpoint of federal aid, Mr. MacDonald called attention to the bill which has just passed both houses of Congress, which authorizes federal appropriations of $ 50 000 000 for each of the years 1938 and 1939, expressly for the separation or protection of grades at crossings, the reconstruction of existing grade crossing separation structures, and the relocation of highways to eliminate grade crossings. In addition to these amounts of federal money, the speaker pointed out that federal gasoline tax collections are accumulating into a considerable sum, which will be available for additional work in increasing the safety of travel on the highways, including that at railway-highway intersections.

In commenting generally on the safety of travel on the highways, and upon the costs of removing hazardous conditions, Mr. MacDonald reminded his audience that, on the basis of the number of fatalities to motorists on the highways, railway grade crossings are not the greatest hazards encountered. In making this point, he showed that whereas approximately 36 000 people were killed on the highways in 1935, only about 1 650 lost their lives at railway-highway grade crossings in that year. Thus, while not belittling the importance of eliminating the hazards at railway grade crossings, he indicated that reducing the hazards at points other than at railway-highway grade crossings was obviously a larger and more important problem.

Touching upon the division of costs for improvements at grade crossings, Mr. MacDonald said that he recognized the Supreme Court decision on this matter as putting an end to the effectiveness of all state statutes requiring that the railway pay an arbitrarily fixed percentage of all grade crossing separation costs. In his opinion, he said, the states should change their laws to the end that the costs of each specific project be assessed against each of the parties involved in direct proportion to the benefits derived. He saw important benefits to the public

in safety and in ease of mind at crossings eliminated, but still larger and increasing benefits to the public, of an economic nature in the free, unrestricted flow of highway traffic at such crossings.

From the standpoint of the railways, he saw some economic benefit in grade crossing protection and elimination, especially in heavy-traffic, high-speed territory, but agreed that, in the end, it was the public generally which benefited by improvements of all kinds at grade crossings, designed to eliminate the hazards to both highway and railway travel and to cause a minimum of interference with the free flow of each.

Mr. Dougherty sees tax assessments too high.

Richard E. Dougherty outlined briefly the character and scope of the extensive West Side Improvements of the New York Central in New York City, commenting at the outset that to comply with his assignment and describe this project, one which has been under study for 30 years and which will have cost approximately $ 100 000 000 when completed, would be rather impossible in the 15 minutes allowed to him. The first phase of this project, which was completed in June, 1934, with the elevation of the road's tracks out of city streets for a distance of approximately 2.3 miles, and the construction of the new St. John's Park freight terminal in lower New York, was described in detail in issues of the *Railway Age* of June 23 and 30, 1934.

In only one departure from the general subject of his comments, brought about by the predominating theme of the program which had to do more with the economic, social and legal aspects of grade crossing elimination and protection than with construction, Mr. Dougherty raised the question of the taxation of improvements at grade crossings. In this connection he said that the present practice, encountered frequently, of high assessments for taxing purposes on grade crossing improvement projects, was unfair and required some adjustment.

A. H. Rudd discusses crossing signals.

Mr. Rudd opened his remarks with an explanation of accident statistics, to show that the accidents at rail-highway grade crossings represent a very small percentage of the total accidents on the highways. He said that since 1924 automobile accidents on rural highways and in areas of 10 000 population or less have increased from 50 per cent to 64 per cent. Statistics show also, he pointed out, that in the six years ending 1934, deaths on the highways have increased 18 per cent, while those at grade crossings have decreased 40 per cent, and, in 1934, only 1/2 of 1 per cent occurred in collisions with trains. A considerable part of this decrease, he felt, may properly be credited to the efforts of the railways. In 1935, he pointed out, only 0.6 of 1 per cent of the so-called highway accidents occurred at grade crossings.

With reference to crossing protection in general, Mr. Rudd explained that there are two schools of thought on the question of highway crossing protection. In this regards, he said :

« One of these groups holds that all that is required is a distinctive indication of the location of a railroad crossing with warning, train approach signal where the view is obstructed or where traffic conditions warrant. This viewpoint is on the basis that the highway user should obey the laws of careful driving and of common sense, and should realize the responsibility which rests on him, not only at railroad crossings, but everywhere else on the highways. Furthermore, this school of thought believes that

the means of giving the information should be standardized. I subscribe to this doctrine.

Statistics can be misleading.

« The other school would impose barriers to the passage of vehicles, some lowered to stop traffic; some swinging horizontally; and one or more rising up out of the ground — and all operated by the passage of trains. The sponsors of these devices present statistics to prove that theirs is the only safe means of reducing the 0.6 of 1 per cent of highway accidents. But do not let yourselves be fooled. I find that the statistics are in many cases misleading even though compiled from official data.

« For example in the report for 1935 of the grade crossing accidents of steam railroads in Pennsylvania, issued by the Public Service Commission, the data shows that of the 674 accidents reported, 58.9 per cent were at unprotected crossings; 16.77 per cent were at crossings protected by flashing-light signals; 8.46 per cent at crossings protected by switching crews; 6.08 per cent at crossings protected by watchmen; 5.34 per cent at crossings protected by gates; 2.97 per cent at crossings protected by bells; and 1.48 per cent at crossings protected by combined alarm and visual signals.

« These bare statistics would appear to prove conclusively that amoung the various types of protection, flashing lights are the poorest; that bells are the best means of protection, except for combined visible and audible signals; that gates are next best and three times as good as flashers; and that watchmen are almost as good as gates. It should be understood, however, that these statistics do not take into consideration density of traffic on either the highways or the railroad, visibility, local conditions, the physical and mental condition of the drivers, or any of the other things which have a bearing on accidents.

« In another place in the report, the number of crossings under each class is shown, from which the percentage of accidents per crossing is calculated as follows : Unprotected, 4.12 per cent; flashers, 11.14; watchmen, 10.2; gates 6.44; bells 11.49; and combined audible and visible signals, 25.64. »

Mr. Rudd explained that the figures given immediately above might be construed as indicating that unprotected crossings are more than six times as safe as those protected by both audible and visible signals; flashers, watchmen and bells ranking about the same. Thus, he pointed out that accident statistics which do not take into consideration all of the factors having a bearing on the accidents, are highly misleading.

Reflectorized crossbuck signs.

Mr. Rudd stated that, in his opinion, if the railroads will erect crossbucks with reflecting buttons at so-called unprotected crossings, on each side of the track, low enough so that they will be illuminated by approaching automobile headlights, instead of erecting the present painted crossbuck, they will have taken a great step forward in helping highway traffic to locate the crossing, which is, he pointed out, a primary requirement if highway traffic is to stop. The installation of these reflectorized crossbuck signs, he felt, would eliminate a demand for automatic devices at a number of crossings where light traffic prevails on either the railroad or the highway.

Automatic crossing signals.

In the final part of his paper, Mr. Rudd reviewed the development and use of several types of crossing signals, describing in detail the flashing-light type of signal which represents a composite of ideas of the members of a committee of the Signal Section, A. A. R. This signal, he pointed out, is not patented,

so that it may be purchased and installed free of any patent entanglements. He explained that the standard auxiliary button-type reflector sign reading « Stop On Red Signal », for mounting below the flashers, was developed to instruct the drivers of highway vehicles as to the meaning of the signal when in operation.

Referring to the use of devices to indicate the approach of a second train at multiple-track crossings. Mr. Rudd contended that, where three or more tracks are involved, the control arrangements necessary for track-operated devices are too complicated to be practicable. As protection under such circumstances, he recommended the use of a reflector button sign showing the number of tracks to be crossed, thus indicating to the motorist that there might be hazards other than that of the train approaching on the nearest track.

Mr. Rudd explained a recent improvement in the use of flashing-light signals as developed by E. W. Reich, signal engineer of the Reading. Where a highway parallels a railroad with cross streets crossing both the highway and the tracks, it has been the practice previously, he explained, to display flashing lights along the highway parallel with the railroad, although such lights do not apply for a through movement on the highway. In the improved signal, he said, instead of using flashers for the highway parallel with the tracks, the Reading has substituted a yellow flasher with an automatically controlled sign reading « No Right Turn » or « No Left Turn », which is illuminated only when a train is approaching.

Present State laws need changing.

Mr. Carruthers confined his remarks largely to the legal aspects of grade crossing elimination, particularly in the state of New York, and first outlined the progress of legislation in this regard in the state. He spoke of the first grade crossing law passed in 1897, which authorized the then Board of Railroad Commissioners to direct the elimination of a highway-railroad grade crossing when *public safety* required it, and which divided the cost 50 per cent to the railroad, 25 per cent to the State and 25 per cent to the municipality in which the crossing was located. In this connection, he laid particular emphasis upon the word « safety », which was the paramount consideration at the time.

He then spoke of the amendment to the state constitution in 1925, in which a state bond issue of $ 300 000 000 was authorized to be used to defray the state's share of grade crossing elimination work and for loans by the state to the railways and municipalities to cover their share of the costs; and of legislative enactments in 1926 and 1928, which produced the present grade crossing laws under which the Public Service Commission and the Transit Commission direct eliminations, and under which the cost of the work is divided 50 per cent to the railroad, 49 per cent to the state and 1 per cent to the county or city.

Commenting upon the present grade crossing law in the state, Mr. Carruthers said that some relief was afforded the railroads through the provision for state aid under which a railroad is able to borrow its share of the cost of an elimination project from the state and repay the loan in 50 yearly installments, but he contended that the 50-49-1 arrangement, relieving the local communities of all costs, had turned out to be a mill stone around the neck of the railroads. In this connection, he said that the increased pressure for elimination from the State Department of Public Works, engaged in the improvement of state highways, and from local municipalities relieved of all elimination expense, has placed such an enormous burden upon the railroads of New York state that some way must be found in the immediate future to give

them relief if progress is to be made in work of this character.

Even though the railroads' cash requirements can be met by state loans, he continued, indebtedness is thus created which they can hardly afford to incur under present economic conditions. He said that the railroads had cherished the hope that the joint resolution, introduced at the recent session of the New York legislature, to amend the state constitution, reducing the railroad's contribution from 50 per cent to 10 per cent, would have been acted upon favorably, but that they were convinced from the action taken that considerable further educational work will be required to bring about such a reduction.

Responsibility now rests on the highways.

Mr. Carruthers recognized the need for suitable safety measures at dangerous crossings, but said that he disagreed with the idea of coddling and nursing the public to the extent that brain muscle becomes atrophied and all personal responsibility is shed in the knowledge that others will perform the act of thinking. Explaining this point, he said that as we relieve the motorist of the necessity for exercising caution at railroad crossings, so do we make him careless under other conditions.

Demand for unobstructed highway travel.

Speaking of the changed conditions which influence the need for grade crossing elimination, Mr. Carruthers said that whereas the paramount influence in the early days was « public safety », the primary consideration today at most points is « public welfare ». Elaborating on this point, he said, in part, as follows :

« The danger of injury or death to the traveler on the highway has been subordinated to the demand for unobstructed highway travel. While I do not believe that lack of merit has crowded the safety feature out of the elimination picture, *crowded out it certainly has been,* and supplanted by a feature that, in my opinion, is more meritorious— namely, the need for removing obstructions to highway travel. This growing need cannot be escaped. I have known of grade crossings on a multiple-track railroad operated intensively, where highway traffic has been obstructed for periods in excess of 20 minutes, and where a line of waiting automobiles has extended for approximately a mile from the crossing. No satisfactory solution of such a problem can be accomplished without separation of highway and railroad grades. But — and I pause for emphasis — *the obligations attaching to elimination are now definitely shifted.* No longer should the railroads be called upon to bear the major portion of the expense. The burden must be assumed by the highway which is adjusting itself to the needs of present-day traffic in this and in many other ways. Government must pay the bill and the railroads must be relieved of a large part, if not all of the cost. »

Enlightened public opinion necessary.

Referring to the decision of the United States Supreme Court in the grade crossing case of the Nashville, Chattanooga & St. Louis Railway against Walters, commissioner of highways of Tennessee, in which, in a decision handed down by the Court on March 4, 1935, the Tennessee grade crossing act requiring the railroad to pay one-half of the total cost of elimination projects was held unconstitutional, Mr. Carruthers said that while this decision was definitely encouraging, it must be taken with certain limitations. Stressing this point, he said, « I repeat, that substantial accomplishment in grade crossing elimination work can be brought about only through educational efforts which, in the end will produce an enlightened public opinion ».

In his closing remarks, referring to the federal assistance being given in grade crossing elimination work, Mr. Carruthers said :

« The present national administration has been criticized for various public works projects undertaken to relieve unemployment, but no one has suggested that the grade crossing elimination work which is has financed since 1933 is not useful and does not serve the general interests of the public. The financing of a limited number of such projects by the government is a step in the right direction, but the work should be divorced from unemployment relief and become a recognized obligation and a fixed policy. Similarly, the various states must assume their share of the obligation. As this necessity is recognized, an equitable division of the cost for grade crossing elimination will be developed along natural lines and the unfair burden now resting upon the railroads will be lifted. To the accomplishment of this result those interested in the welfare of the railroads must give their most serious attention. »

[621. 132.2 (.42)]

RECENT DEVELOPMENTS
IN RAILWAY PRACTICE.

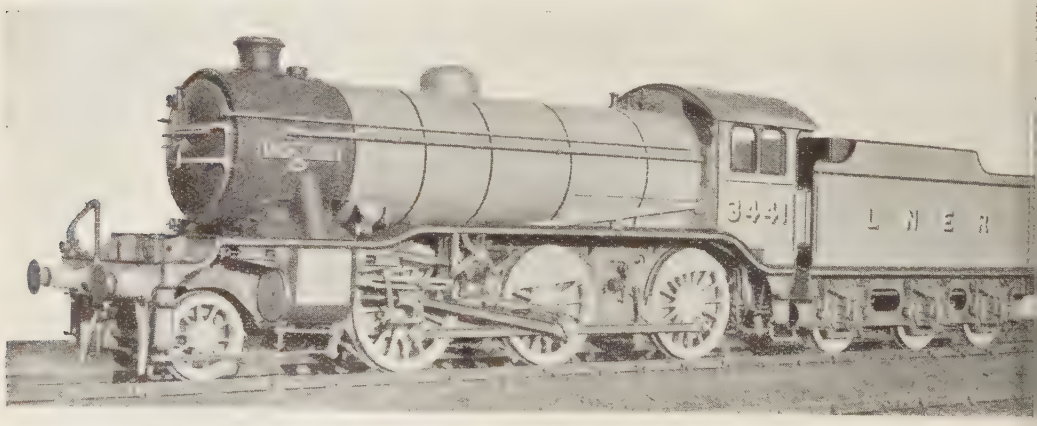
New 2-6-0 locomotives for the London and North Eastern Railway.

In order to avoid double heading on the heavily graded West Highland Line of the L.N.E.R., where axle loads are strictly limited, a new type of three-cylinder 2-6-0 type locomotive has been built at the Darlington Works to the design of Sir Nigel Gresley, C. B. E., D. Sc., the Chief Mechanical Engineer, to whom we are indebted for the present information. The engine is numbered 3 441 and has been named « Loch Long ». It is fitted with the standard 3 500-gallon tender.

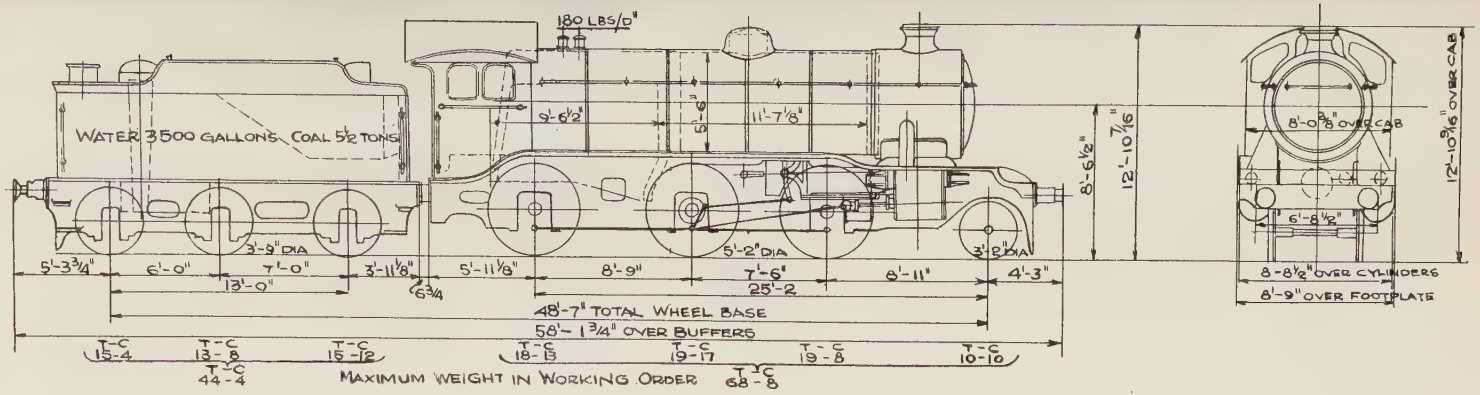
The pony truck is of the double swing link pattern with a translation of 4 1/2", and has wheels 3'2" diameter. The coupled wheels are 5'2" in diameter.

Three cylinders, 18 1/2" diam. × 26" stroke, cast in one piece, drive the second pair of coupled wheels. The piston valves are 8" diameter, with a maximum travel of 5 5/8" and a maximum cut-off of 65 %. The outside valves are operated by Walschaerts valve gear, and the inside valve is actuated by the Gresley system of two to one and equal levers from the outside valve spindles. The valve gear and nickel-chrome connecting and coupling rods are standard with those used on the Company's K. 3 type engines.

Cylinder and axlebox lubrication is effected by means of Wakefield mechanical lubricators.



The boiler barrel is 5' 6" diameter and 11' 7 1/8" between the tubeplates. The firebox has a grate area of 27.5 sq. ft. and is fitted with narrow firebars giving 56 % air space. Two 3" diameter Ross pop safety valves are set to blow off at a working pressure of 180 lb. per sq. in. and a Robinson type 24-element superheater is fitted. The boiler is fed by a Davies & Metcalfe No. 9 class H exhaust steam injector on the right hand side, and a Gresham & Craven No. 10 live



Leading dimensions and ratios.

Grate:

Length on slope	8' 5 1 2"
Width	5' 4 3,8"
Grate area	37.5 sq. ft.

Firebox:

Height of crown above \ front	6' 1 3 4"
foundation ring / back	5' 0 1 2"
Interior length at top	8' 2 5 8"
Interior width at boiler centre	4 7 7 8"
Thickness of \ sides and back,	9 16"
copper plates / tubeplate	1"

Boiler:

Outside length of firebox, over-all	10' 0 1 2"
Outside length of firebox at bottom	8' 11"
Outside width of firebox at bottom	5' 0 1 2"
Maximum diam. of barrel	5' 6"
Thickness of barrel plates	5 8"
Thickness of wrapper plates	1 2"

Tubes, small:

Material	Steel.
Number	164
Diameter outside	1 3,4"
Thickness	11 S. W. G.

Tubes, superheater flues:

Number	24
Diameter outside	5 1/4"
Thickness	5 32"
Length between tubeplates	11' 7 1 8"

Heating surface:

Firebox	168.0 sq. ft.
Tubes	871.1 —
Flues	382.5 —
Total evaporative	1421.6 —

Superheater:

Number of elements	24
Diameter inside	17 32"
Heating surface	310 sq. ft.
Total heating surface	1731.6 sq. ft.
Two Ross pop safety valves	3" diam.
Working pressure	180 lb. p. sq. in.

Axles:

	Dia.	Len.
Journals, pony	6 1 2"	× 9"
— coupled	9 1 2"	× 11"

Crank pins:

Outside	5" × 5 1/2"
Inside	8 1/4" × 5 1/2"

Coupling pins:

Leading	4 3/4" × 4"
Driving	6" × 4 1 2"
Trailing	3 1 2" × 4 1/2"

Springs — Pony: Helical, 10 1/2" long free, 5 1/16" outs diam., Timmis section. Coupled wheels: Laminated 15 plates 5" wide × 1 2 thick. 4' 0" ers.

Cylinders:

Number	3
Diameter	18 1 2"
Stroke	26"

Motion:

Type: Outside	Walschaerts.
— Inside	Gresley.
— Valves	Piston.
Diam. of valves	8"
Max. travel of valves	5 5 8"
Steam lap, outs. cylinders	1 5 8"
Steam lap, ins. cylinders	1 11,16"
Exhaust lap	Nil.
Cut-off in full gear	65 %.

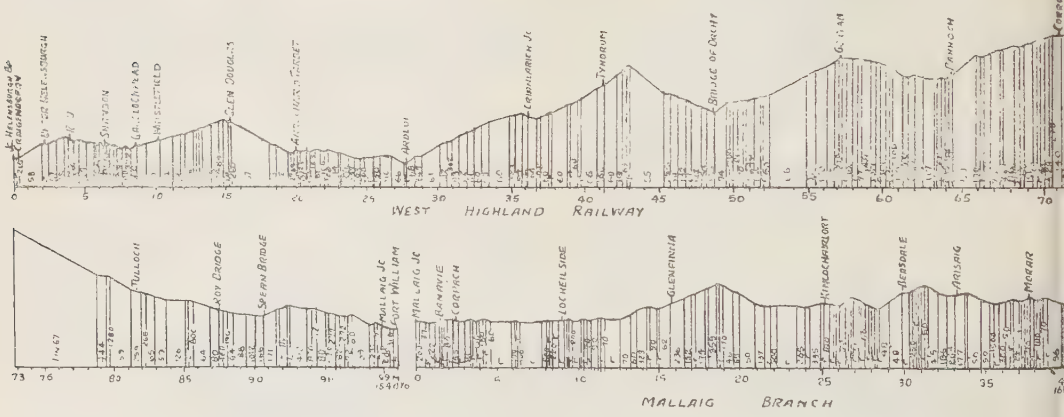
Tractive effort at 85 % boiler pressure	32 939 lb.
Total adhesive weight	129 696 lb.
Adhesive weight / Tractive effort	3.9
Brakes	Vacuum.

steam injector on the left hand side. The boiler barrel is insulated with asbestos blocks, and the firebox with asbestos mattresses.

Vacuum brake is fitted to both engine and tender, and steam heating apparatus is provided.

The following comparison between the K. 3 and K. 4 type engines is of interest :

Type.	Cylinders. Diam.	Cylinders. Stroke.	Driving wheel diam.	Boiler pressure.	Weight in working order. Engine.	Weight in working order. Tender.	Total heating surface (including superheating surface).	Grate area.	Tractive power at 85 % boiler pressure.
				lb.	t. cw.	t. cw.	sq. ft.	sq. ft.	lb.
K. 3	18 ½"	26"	5' 8"	180	72 10	52 0	2 308	28	30 031
K 4	18 ½"	26"	5' 2"	180	68 8	44 4	1 732	27.5	32 939



The West Higland Section of the L.N.E.R. begins at Craigendoran Junction, which is about quarter of a mile east of the station, and the country traversed from this point to Fort William and from Fort William to Mallaig is exceedingly difficult. The above profile of the line shews the severe gradients encountered.

MISCELLANEOUS INFORMATION.

[621. 133. 7]

1. — Locomotive feedwater treatment.

Water-softening.

(*Modern Transport.*)

In the course of a paper entitled « Locomotive feedwater treatment », read at a meeting of the Institution of Locomotive Engineers on November 25, Mr. J. S. HANCOCK said that the chemical treatment of locomotive feedwater had come rapidly to the fore during the past twenty years, first in America and more recently in Great Britain. The earliest attempts at improving the quality of locomotive feedwater on English railways were made between 1890 and 1900, when water softening plants were erected at a number of points where unusually hard waters had to be used. One of the earliest of these plants, erected on the Midland Railway at Derby in 1890, was still operating. In those days the object of water treatment was simply to remove scale-forming impurities. Today, as the result of a wider experience, it was realised that economies in boiler maintenance were obtainable not merely by preventing the deposition of scale, but by extending the life of the boiler through the reduction of corrosion.

Experience had also proved that a mixture of softened and unsoftened waters was invariably a corroding water, and that water treatment, to be successful, must be applied not merely to a few hard waters, but to all the feedwater entering a locomotive boiler. The prevention of corrosion by removing the oxygen from the feedwater was not feasible either by chemical of mechanical means, and it was necessary, therefore, to look elsewhere for a suitable remedy. A method of preventing boiler corrosion by chemical treatment of the feedwater existed, and has been used with success by American railroads for the past fifteen years. That consisted in treating the feedwater with suitable chemicals, so that a small quantity of free caustic soda remained at all times in solution in the boiler water.

In America, prior to 1920, when the rule of softening was not to soften below 4 deg., the average life of steel fireboxes was from four to five years, and of tubes from two to three years. The average life of tubes and fireboxes at the present time was approximately twelve years, as the result of treating the bulk of the feedwater.

Water softening.

The type of plant commonly used for softening locomotive feedwater was the lime-soda plant in which hydrated lime and soda ash where used to bring about the required chemical reactions. Those reactions were as follows :

CHEMICAL REACTIONS IN LIME-SODA SOFTENING PROCESS.

1. $Ca(HCO_3)_2$ + $Ca(OH)_2$ = $2CaCO_3$
   Calcium Bicarbonate (soluble) — Lime — Calcium Carbonate (insoluble)

2. $CaSO_4$ + Na_2CO_3 = $CaCO_3$ + Na_2SO_4
   Calcium Sulphate (soluble) — Soda Ash — Calcium Carbonate (insoluble) — Sodium Sulphate (soluble)

3. $MgSO_4$ + $Ca(OH)_2$ + Na_2CO_3
   Magnesium Sulphate (soluble) — Lime — Soda Ash

   equals

   $Mg(OH)_2$ + $CaCO_3$ + Na_2SO_4
   Magnesium Hydroxide (insoluble) — Calcium Carbonate (insoluble) — Sodium Sulphate (soluble)

Calcium carbonate was able to enter into solution in natural waters by combining with the dissolved carbon dioxide to form calcium bicarbonate. In water-softening the hydrated lime combined with this carbon dioxide, set-

ting free the calcium carbonate which was rendered insoluble. Calcium, which was present as sulphate or chloride, was removed by soda ash, which converted the calcium sulphate to insoluble calcium carbonate, leaving in solution an equivalent amount of sodium sulphate. Magnesium, which was present as sulphate or chloride, required hydrated lime for its removal as well as soda ash; in that case the magnesium sulphate was converted to insoluble magnesium hydroxide and an equivalent amount of sodium sulphate was brought into solution.

The modern water-softening plant was, Mr. Hancock said, a continuously operating plant; that was, the chemicals were added and the chemical reactions proceeded as the water flowed continuously trough the plant. The features of a modern plant were :

(1) Apparatus to apportion the lime and soda to the incoming raw water.
(2) A reaction chamber of at least 15 min. capacity in which the mixture of chemicals and raw water was thoroughly agitated by means of revolving paddles.
(3) A settling tank of such dimensions that the water was retained at least 3 hours with an upward rate of flow not exceeding 5 ft. per hour.
(4) A filter, either of sand or wood wool, to remove the last traces of precipitate.
(5) On the bottom of the reaction tank a system of collecting pipes and valves to discharge the accumulated sludge.

The precipitate formed by the chemical reactions between hard water and lime and soda ash was formed of very small particles which were difficult to settle and might be carried into the filters by the moving water. This was overcome by using a small quantity of alum or sodium aluminate, the particles of precipitate, instead of being small and light, being coagulated into large groups which readily fell to the bottom of the tank.

Locomotive operation.

Softening of locomotive feedwater invariably resulted in « priming », especially if the water was reduced to a low degree of hardness by the use of lime and the maximum dosage of soda ash. Since priming interfered with the running of trains it must be eliminated at all costs, and that was often done by reducing the amount of soda ash used at the water-softening plants, thus providing a water which was only partially softened. Alternatively, priming might be eliminated by reducing the boiler washing-out or water-changing mileage. The effect of water-softening upon the mileage which could be run before priming commenced was very great. For example, it was necessary, following the introduction of water-softening on a section of a British railway, to carry out changes of boiler water every 500 miles in addition to the customary boiler wash-out at 2 500 miles.

If the rate of evaporation and the working water level remained fairly constant, priming could be brought about in one way only; that was by raising the sodium salts in the boiler water to the priming concentration, which, in the case of locomotives in Great Britain, varied usually from 150 grains per gallon for small engines to 200 grains per gallon for large passenger engines, although instances of higher concentration were sometimes reported. When the critical concentration of soluble salts was reached, priming took place intermittently and sufficient boiler water was carried away with the steam to prevent further increase in the concentration. The mileage which could be run before priming commenced depended upon the rate at which the sodium salts accumulated in the boiler; that was, upon the amount of sodium salts in the feedwater and the rate of evaporation. In the case of a boiler the water capacity of which was 1 500 gallons and average evaporation 30 gallons per mile, fed with water containing 4.5 grains per gallon of soluble salts, the critical priming concentration of 200 grains per gallon would be reached at 2 200 miles after washing out, provided no carry-over was taking place.

[621. 135.2 & 656. 284]

2. — Locomotive-tyre failures.

(Engineering).

Some interesting figures with regard to locomotive-tyre failures appear in the report of the Committee on Locomotive Construction, placed before the Association of American Railroads at their 1936 Annual Meeting. These figures, which refer to the twelve months ending December 1, 1935, are obtained from the reports of 59 leading railways owning between them 35 458 locomotives, but the Committee are careful to point out that they are not entirely confident of the completeness of the information received, as the distribution of recorded failures between the reporting lines is sometimes very uneven, no fewer than 68 of the small administrations reporting no failures at all, while a number of reported failures cannot be classified in the absence of sufficient detail.

The number of recorded failures is 613, of which 212 are classified as due to manufacturing processes, and 238 to railway responsibility, while 163 could not be classified. Of the 212 failures ascribed to manufacturing processes, that is, to defects inherent in the tyres before the railways acquired them, 51 caused breakage, and of the broken tyres 45 were from driving wheels. On the other hand, in the remaining 161 cases in which the tyres were taken out of service but not broken, 40 were driver and 121 trailer tyres, thus reversing the proportion. The difference is due to the large number of trailer tyres rejected for what are termed « shelled treads », totalling no less than 120 of the 121 reported, while of the 40 driver tyres withdrawn only 14 are shown under this head. Apart from shelled treads, therefore, driver tyres account for 71 out of 78 failures, a result which might have been anticipated.

The condition described as « shelled tread » is one that appears to have come to notice fairly recently, and consists of a flaking or spalling of the tread, gradually increasing in depth, and, in extreme cases, extending right round the tyre. It is found in uniform sound steel with no suggestion of defective metal, and, as has been indicated, most frequently in trailer tyres, in which the small diameter and high peripheral speed combine to induce higher stresses than in the larger driver tyres. Microscopic examination has shown that the shelling is formed by a series of cracks running at an angle of approximately 45° to the surface of the tread, and with other cracks branching off from these, roughly at right angles, up to the surface thus producing the flaking effect. The cracks suggest failure under compression, and it has been found that the application of heavy rollers to steel tyres with a pressure in excess of that required to produce permanent distortion, causes, in a limited number of revolutions, pitting and finally spalling similar to that found in shelled treads; also that the greater the load above the yield point, the fewer the number of revolutions required to produce spalling. It is thus definitely indicated that shelling is a fatigue type of failure under compression stress, undoubtedly affected and aggravated by speed, by the slip and drag of tyres on curves, by sudden cooling of the heated tread metal, such as may occur in winter, by passing over rail joints and crossings and so forth. The methods of dealing with this trouble have not yet been fully formulated, and will require further investigation. The instructions hitherto given by the Association have been that such shelling should be turned out if it had penetrated less than 3/8 in. below the surface of the tread, and the Committee think that these instructions have led in many cases to such shelled treads being turned up without report, as they cannot otherwise account for numerous failures of this nature being reported by certain lines, while others mention none. They now desire that all cases, whether the tyres have been turned up or discarded from service should

be reported, with full particulars as to the depth of the shelling, the type of wheel centre, and, in the case of a trailer tyre, whether the wheels are booster-driven or braked.

It is thought that local conditions will largely affect the treatment required, and it has already been found that in certain cases the use of a higher carbon steel has produced improved results, while experiments have also been made with heat-treated tyres. This last remedy has, however, its own drawbacks, as shown by the fact that of the 15 cases of tyre breakage, classified in the report as due to cracks in the bore, 14 occurred in heat-treated tyres. The Committee in this connection dwell on the importance of such tyres being fully and uniformly supported by the rim of the wheel centre. If, owing to distortion of the wheel centre, or improper shimming, or corrosion in the bore of the tyre, the support is not uniform, flexure results to which a tyre of low elastic limit may adapt itself, whereas a heat-treated tyre of higher elastic limit may fail. During the period June 1 to December 1, 1935, a considerable number of failures were attributable to this cause. The Committee feel that much investigation is required before heat treating can be standardised, and it is probable that the type of heat treating to be adopted will depend on the service conditions to be encountered. The Committee adds its doubt as to « whether mechanical officers or their subordinates generally appreciate the large number of tyre failures traced to cracks in the bore developing from rough tool marks, nicks and corrosions, wheel centres out of round, and welding and torch burns ». Of the 238 failures attributed to railway responsibility, 164 come under this head, thus emphasising the need for care in these matters. Of the remainder, 56 are classified as due to thermal cracks, and eight to excessive shrinkage.

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

Final summaries adopted at the thirteenth Session (Paris, June 1937).

SECTION I. — Way and Works.

QUESTION I.

The construction of modern track to carry heavy loads at high speeds, and methods of modernising old track for such loads and speeds. Facing points which can be taken at high speeds.

Summary.

« 1. Except on the Railways in North « America, where the axle load reaches « 35 tons, the general limit is 20 tons. « The tendency of the rolling stock de- « signers at the present time is to make « it 20 to 25 tons, according to the Rail- « ways concerned.

« The speed of 120 km. (75 miles) an « hour, the usual maximum for a long « time for passenger trains, has been « exceeded in many cases. The tendency « at the present time is to authorise « speeds of about 150 km. (93 miles) « an hour for ordinary trains, and 160 « km. (100 miles) an hour for railcars « and rail motor trains.

« Under these conditions, the track « stresses will henceforth include an in- « creasing part due to the dynamic « effects of the loads moving at high « speeds. It is desirable, for this reason, « that these dynamic effects should be « investigated by means of experiments, « tests and measurements in all the « fields in which they may show them- « selves, both to guide the builders in « finding suitable ways of balancing and « distributing the forces, and to appre- « ciate the stresses the track must be ef- « fectively able to stand.

« 2. The heavy loads and high speeds « impose upon the present-day rail me- « tal a stress which in most cases it « would be difficult to increase without « affecting the behaviour and life of « rails.

« The weight of the rails on the most « heavily loaded lines in Europe is about « 50 kgr./m. (100 lb. per yard). There « are still differences of opinion as to « the desirability of increasing the « weight of the rails to meet the increas- « ing stress resulting from the loads and « speeds.

« The length of the rails and the type « of rail joint vary much, according to « the Railways. The conditions of use of « extra long rails are still under investi- « gation and cannot be determined exact- « ly at present.

« 3. The wooden sleeper is at present « generally considered as being the most « suitable for very high speeds.

« Increasing the sleepering is one of « the methods which contribute to the « strengthening of the track in order to « enable it to carry the heavier loads « with the least damage, and to offer a « better resistance to the lateral and ver- « tical forces caused by the high speeds.

« Vehicles running at high speed un- « der satisfactory conditions as regards « comfort and safety require the track

« to be perfectly level as well as in good « alignment, and correct to gauge. « These conditions can only be fulfilled « if the fastenings securing the rails to « the sleepers are perfectly maintained « and tightened up. The use of bearing « plates between the rails and the slee- « pers, with suitable fastening devices, « is the general practice on many rail- « ways, and appears desirable, at least in « those parts of the track which include « curves of small radius.

« 4. Increasing the thickness of the « layer of ballast enables a better distribu- « tion to be obtained of the loads and « vertical forces sustained by the track « when vehicles are passing over it.

« The ballast should be sieved, homo- « geneous and of good permeability, and « consist of broken stone, the dimen- « sions of which should not exceed 6 to « 7 cm. (2 3/8″ to 2 3/4″). Tests with « the ballast before delivery are desi- « rable.

« The roadbed should be sound and « properly drained to prevent water re- « maining on the ground in cases in « which its permeability is known to be « poor.

« In order to avoid the clogging of the « ballast, it is desirable that the ashpans « of locomotives shoud be closed.

« 5. Advantage should be taken of the « opportunity offered by track overhaul « or renewal work, for modernising old « track and obtaining the conditions « stated above.

« The alignment and levelling up of the « track should be perfect in view of the « speeds now run. Curves and their « transitions should be very carefully « laid, and be maintained and corrected « as often as necessary.

« It is desirable to determine, by sui- « table experiments, the limits of speeds « which can be readily admitted for the « passage of trains through a curve, by « taking into account its radius, its su- « per-elevation or the insufficiency of « this latter.

« The state of perfection necessary in « the maintenance to enable high speeds « to be used involves considerable sup- « plementary expenditure, and this ex- « penditure must be taken into conside- « ration when it is proposed to use such « high speeds.

« 6. The angle of divergence at the point « of the blade should be as small as pos- « sible; the blade should be flexible, so « as to give the track a progressive cur- « vature when entering the switch.

« The radius of curvature of the part « of the track connecting the switch to « the crossing should be as large as pos- « sible, to guide the vehicle up to the « crossing.

« All causes of shock or interruption « in the running surface and guiding « of the axles should be avoided by a « careful lay-out of the whole of the « points and crossing and of the two li- « nes of rails.

« The crossing angle should be as « small as possible, and the crossing, like « the whole appliance, should be rigid « and remain perfectly secure.

« The super-elevation of the curved « parts should be computed in each par- « ticulier case, according to the rules ap- « plying to the running road. The speeds « to be allowed should be fixed and « checked by tests with the various types « of vehicles that have to be used. »

QUESTION II.

Application of welding:

1. **To obtain extra-long rails;**
2. **In manufacturing and repairing points and crossings.**

a) **Results obtained by using extra-long rails. Methods used to ensure safe expansion of the rails and anchoring of the track.**

b) **Technical and financial results shown by welding points and crossings.**

Summary.

« 1. The application of welding processes to track equipment in order to increase the length of rails hardly dates back more than six years. In spite of its recent introduction, welding has not only given rise to progress in track construction, but also to appreciable savings in the expenditure necessary for laying and maintaining the track.

« The chief advantage conferred by welding is that rail joints can be appreciably reduced in number, or even entirely eliminated on long track lengths. Moreover, welding enables composite rails to be constituted by welding together two rails of different profiles, which is an excellent means of abolishing special fish-plates, which fish-plates often are a cause of dislocation.

« It is desirable that studies and experiments should continue to be carried out with regard to the behaviour of long welded rails on running lines, under the heavy rolling loads, as well as to the width of the joint gap with different lengths of rail and different temperatures.

« Moreover, the use of extra-long rails not only ensures smooth and comfortable riding of the vehicles, but such vehicles are also subject to lesser fatigue.

« On bridges, the welding of the joints appreciably diminishes the dynamic effects, which contributes to the preservation of the whole of the different parts of the structure.

« Savings may therefore be looked for in the expenditure necessary for maintaining and building vehicles and bridges, economies which will be all the more appreciable on those sections of line where the longest lengths of track are laid with long rails.

« Similarly, the use of welded rails should be considered for heavily loaded lines in marshalling yards when the ballast and side-ballast are compact and well knitted together, as the risks of transverse deformation are thus very much reduced.

« It is desirable that the welding of rails should be checked during execution, by means of suitable tests (mechanical and metallographic).

« 2. By the use of welding for joining rails and other track components, particularly when fabricating points and crossings, it is possible to reduce the number of fastenings subject to heavy wear. The resistance to wear and the life of points and crossings will be increased thereby.

« 3. Building up by welding is a means of reconditioning running surfaces worn locally, and consequently of again lengthening the life of rails and crossing components.

« 4. This results in substantial savings on the maintenance costs of the track and avoids interference with traffic working.

« As regards the various welding processes, which are still in the experimental stage, an endeavour is made,

« by means of observations, studies and « experiments, to find out, for each « kind of weld, which process is the « best from the double point of view of « quality and economy. The results ob- « tained in a short time are so promising « that it is proposed everywhere to still « further extend the use of welding in « track work. There is every hope that « future progress in this still new field « will prove beneficial for the railways « and their respective countries. »

QUESTION III.

Methodical and periodical maintenance of :

1. metal bridges; 2. signals; 3. metal supports carrying the contact wire on electric railways.

Organisation. — Working methods. — Materials used.

Summary.

« 1. It is advisable that the staff res- « ponsible for the design and construc- « tion of metal bridges should directly « or indirectly intervene in the main- « tenance of such structures.

« 2. Depending on the size of the « bridge, the use of pneumatic or elec- « tric de-rusting apparatus will, in cer- « tain cases, reduce maintenance costs.

« 3. When periodical re-painting is « undertaken, it is sometimes unneces- « sary to treat large surfaces, which are « still in a good state of preservation, « in the same manner as necessary for « other surfaces, unless æsthetic con- « siderations require it; in such a case it « should be sufficient to apply only the « final coat.

« 4. With a view to avoiding the con- « tingency of removing scaffolding, it « is advisable to apply a binding mate- « rial which makes it possible to apply « the following coat of paint soon after « the previous coat is put on.

« 5. The use of spray-painting can, « in certain cases, enable a saving in « the re-painting of bridges to be ef- « fected.

« 6. De-rusting work and the appli- « cation of red lead and other paint, « carried out by the Railway's own staff, « may offer advantages from the point « of view of the quality of the work, « as compared with the work executed « by contractors.

« 7. In view of the increased train « speeds, it is advisable, in order to « ensure better preservation of bridges, « to use rails assembled by welding in « order to avoid joints.

« 8. At the ends of movable bridges, « it is advisable to provide arrangements « not giving rise to shocks from the pas- « sage of trains.

« 9. Savings can be effected in many « instances, and interference with the « running of the traffic avoided, by the « use of electric welding for repairing « and strengthening bridges.

« 10. The flanges of girders subjected « to engine chimney blast can, in cer- « tain cases, be protected by means of « reinforced concrete.

« 11. It appears advisable to appoint « a special division or section for main- « taining signal apparatus, together with « all telegraphic and telephonic means « of communication.

« 12. Periodical checking of the lumi- « nosity of signals is not thought to be « necessary by all Administrations; the « reports of the locomotive running de- « partment staff are considered from

« their point of view sufficient for « pointing out defects of signals.

« 13. It is desirable that maintenance « staff responsible for checking the de- « tector slide clearance use a special « gauge.

« 14. It is, as a rule, advisable, to « slightly under-run signal lamps.

« 15. The use of enamelled iron signal « arms is, in the long run, more econo- « mical.

« 16. It appears unnecessary to remove « track circuit relays for periodical exa- « mination if well-trained staff are avai- « lable who can examine them in situ « without any interruption of the traffic.

« 17. With a view to eliminating or « reducing re-painting of supports car- « rying the overhead contact wires, it « appears that complete galvanisation of « the supports gives the best results.

« 18. Metal spraying of supports car- « rying contact wires does not always « provide sufficient protection against « rusting of steel parts.

« As a precautionary measure, a final « coat of linseed oil paint should be « applied, in order to fill up any pores « which may have been left as the result « of the metal spraying.

« 19. The use of supports consisting of « rolled sections with side flanges which « have the tie-rods or brackets clamped « instead of being bolted or rivetted, « lowers the initial, as well as the main- « tenance costs in the majority of cases. »

2nd SECTION. — Locomotives and rolling stock.

QUESTION IV.

Evolution of the rail motor car as regards its construction, and special investigation into the transmission and brake questions. Comparative methods of testing railcars. Detailed investigation into the cost of railcars and methods of reducing them.

Summary.

« 1. Satisfactory technical solutions « have been found in the course of the « last two or three years to the speed, « acceleration, braking and safety pro- « blems.

« The future of the railcar now de- « pends on the solutions that will be « adopted as regards comfort, economi- « cal maintenance and capacity. This fu- « ture also depends on future improve- « ments of the track (curves, superele- « vation, elimination of rail joints or « reduction of their number), and espe- « cially on the mutual adaptation of « the rail motor car, operating methods, « and traffic requirements.

« 2. Railcar diesel engines can be di- « vided into three classes :

« *(a)* 600-H.P., and over, engines, rela- « tively heavy, but very economical as « regards working and maintenance ; « such engines are used extensively in « the United States of America;

« *(b)* 300 to 600-H.P. engines weighing « about 5 kgr. (11 lb.) per H.P., as adopt- « ed by most European Railways;

« *(c)* Up to 300-H.P. engines, amongst « which the Czechoslovak, German and « French horizontal engines deserve spe- « cial mention.

« By the use of supercharging, which « tends to extend, the weight/power ratio of engines can be reduced; improved behaviour of the motion and better « dissipation of the lost heat units are « also obtained.

« 3. Mechanical transmissions are « quite satisfactory, as regards weight, « cost and efficiency, up to 300-H.P., and « allow the coupling up of two or three « vehicles. Mechanical transmissions for « 450 and 500-H.P. are being tested in « Italy and in France.

« Electrical transmissions are now « fully perfected for all powers, giving « full satisfaction for services on mountain lines and for multiple-unit working.

« Hydraulic transmissions have made « definite progress in the course of the « last two years, in respect of all powers « and engine speeds, in Austria and Germany; they also allow of multiple-unit « operation, even when coupled up to « electrical-transmission units.

« 4. All Administrations are adapting « the suspension of their railcars to the « permanent way, as it is at present « constituted and maintained.

« In order to reduce to a minimum « the vertical movement of bogies, and « to improve comfort, Railways are now « using wheel tyres coned 1/40, cylindrical tyres, multiple suspension gear « and rubber shock absorbers. Such devices have not given rise to any difficulty, and their use can be recommended.

« Some Administrations also use devices to damp out hunting movements « and vertical vibrations, bogies (articulated or not) with six or eight « wheels, loose wheels revolving on fixed « axles, axleboxes without axleguards, « etc. All these solutions have given « them satisfaction.

« 5. Block brakes are most generally « employed at present; they are electrically controlled in certains countries « (U. S. A., Czechoslovakia) and improved, in the case of high-speed working, « by the use of Decelakrons or regulators « giving pressure on the blocks, increasing with the speed.

« Amongst new brakes, the disk brake, « the eddy-current brake and the N. R. « brake with double shoes, should be « mentioned.

« 6. Sound-proofing and air-conditioning are particularly resorted to at « present in order to increase comfort.

« Steel-tyred vehicles — although they « cannot claim the same comfort as « pneumatic-tyred vehicles can be improved from the point of view of noise, « particularly by double partitions with « air cushion, of pulverised felting, rubber, and the careful stopping up of all « openings.

« Air conditioning, and air cooling in « summer (by means of ice or freon), « are particularly appreciated in vehicles « with fixed window lights.

« 7. Maintenance costs and amortization charges are the biggest items in « the cost price of diesel-engined cars.

« Several Administrations are seeking « above all a reduction of maintenance « costs by using preferably relatively « slow motors of heavy construction.

« Other Administrations desire maximum lightness in order to increase the « possibilities of the railcar and to reduce the running cost; they consider « that the progress made in the matter « of lightening will allow them to arrive « at a reasonable maintenance cost.

« The Congress considers it desirable « that the Railways agree to calculate in « a uniform way the coefficient of use « of their railcars and their cost price.

« 8. Most Administrations, in order to « improve their operating costs, and to « give satisfaction to the public, tend to « replace their train services by railcar « services and, in this connection, to in- « crease more and more the capacity of « the railcars.

« As regards general design, various « solutions are being resorted to : rail- « cars with engines placed underneath « the floor, twin-railcars, or single rail- « cars coupled together, railcars hauling « trailers and multiple units.

« 9. The Congress considers it desira- « ble for the Railway Administrations to « adopt a common test method for ascer- « taining the characteristic constants of « their railcars.

« On the other hand, the nominal po- « wer of internal combustion engines « should be given the same definition in « all countries. »

QUESTION V.

Recent improvements in steam locomotives of the usual type and tests of new designs (high-pressure reciprocating locomotives and turbine locomotives) as regards construction, quality of materials used, efficiency, working conditions, maintenance and financial results.

Testing locomotives at locomotive experimental stations, and in service with dynamometer cars and brake locomotives.

Summary.

« 1. There has not been any marked « increase in boiler pressure since 1930. « A pressure of about 284 lb./sq. inch « (20 kgr./cm^2) can be regarded as the « generally observed limit for boilers of « conventional design.

« A total steam temperature of about « 752° F. (400° C.) appears to be the ma- « ximum compatible with good lubrica- « tion, and the creep effect of the metals « in contact with the steam.

« 2. The enlarging and improving of « the live and exhaust steam pipes and « passages has reduced the drop of pres- « sure between the boiler and cylinders « and has facilitated the discharge of the « exhaust steam, thereby improving the « steam circuit.

« 3. Interesting progress has been rea- « lised in the design of the exhaust, « whereby the counter-pressure has been « reduced, combustion improved, and the « thermic efficiency of the locomotive « improved.

« 4. The scientific streamlining of lo- « comotives appreciably reduces air « resistance at high speeds, and there- « fore increases the horse-power availa- « ble for traction.

« Streamlined locomotives of the reci- « procating type, specially designed for « extra high speed working, have been « introduced by several Administrations « since 1930.

« 5. Tests are being carried out with « turbine locomotives, with a tendency « to abandon condensation.

« 6. Testing stations are regarded as « essential for the scientific study and « the precise and comparative investiga- « tion of the design, performance and « efficiency of locomotives and their « components.

« 7. Trials with dynamometer cars in « conjunction with brake locomotives « form the best method of determining

« the maximum drawbar horse-power « and fuel consumption of locomotives « under service conditions.

« 8. It is desirable that all Railways « should agree a standard programme « for the testing of locomotives, both at a « testing station and under service con- « ditions with dynamometer car and « brake locomotive, so that accurate com- « parative results can be obtained. »

QUESTION VI.

Methods and devices used, in connection with electric traction, to save current between the supply side of the power station and the driving wheels (feeders, substations, tractors), and in particular the use of mercury rectifiers.

Summary.

« 1. Proposals for saving current can- « not be considered on purely technical « grounds, but must be related to the « total cost to the railway, of the service « performed.

« 2. In addition to the savings due to « improvements in the equipment, which « cannot be expected to make a great « difference in the total energy consump- « tion, direct savings in the energy re- « quired and in the recovery of energy « by regenerative braking demand serious « consideration.

« 3. The most important contribution « of recent years to the improvement of « electric traction equipment is the mer- « cury vapour converter.

« This type of equipment has not yet « reached its full development; it is how- « ever possible to predict that, in the « near future, this development will reach « a point where the mutator will replace « the rotating converter in the same « measure as the rectifier at present re- « places the rotary converter for the con- « version of alternating current to direct « current.

« 4. The mercury vapour inverter has « proved satisfactory on one Administra- « tion for reconverting direct to alternat- « ing current in the substations of di- « rect-current lines employing regene- « rative braking. This will no doubt in- « duce other Administrations with di- « rect-current systems to seek further « improvements in the same direction.

« 5. The fixed frequency ratio mutator « has given satisfaction for the conver- « sion of three-phase current to single- « phase current of low frequency « (Reichsbahn).

« Several types of mutators of variable « frequency ratio have been tried. It « cannot, however, be predicted yet, « which of these systems will eventually « give satisfaction.

« 6. Grid control equipment is an in- « herent part of the mercury vapour con- « verter for all uses except as a rectifier. « In addition to its main function the « equipment can also be adopted for all « types of mutators to control the out- « put voltage and to interrupt the main « arc.

« 7. In cases where ripples in the out- « put of a mutator cause interference in « communication or signal circuits, the « provision of resonant shunt filters « provides a satisfactory solution.

« 8. The water-cooled steel tank type « unit is the most widely used, but the « glass bulb type, and also the newly « developed low-capacity air-cooled type « form useful alternatives for some ap- « plications.

« 9. The substations should be situated « at sufficiently short intervals to ensure

« a low voltage drop in the contact « system, although only the minimum of « copper and other materials is used in « the construction of the contact system « itself and in the substations.

« 10. On alternating-current lines this « can be effected by the introduction « between substations of intermediate « feed points provided with a simple « transformer controlled either from the « nearest railway station or by a remote « control system.

« 11. On direct-current lines the same « results can be obtained by the use of « remote-controlled single-unit rectifier « substations.

« 12. The additional cost of remote « control as compared with completely « automatic control is normally justified « by the increased flexibility given to « the system.

« 13. The mobile substation can some- « times be used with advantage to meet « temporary operating needs.

« 14. On alternating-current lines oper- « ating at high voltage the contact system « losses are readily reduced to a reason- « able value and any special steps are « usually needed to prevent communica- « tion circuit interference rather than to « save current.

« 15. On direct-current systems the « losses are higher, and special consi- « deration must be given to the question « of securing a reduction. Apart from « increasing the conductor rail section, « these include improved bonding of « tracks and contact circuits.

« 16. The weight of electric locomo- « tives for equal horse-power and trac- « tive effort has been considerably re- « duced during the last few years.

« 17. Weight reduction, particularly on « motor coach stock, is the most impor- « tant means of saving energy. This may « be attained by changes in construction « and by the use of special materials. « Changes in construction include the « combination of the body with the un- « derframe and the use of welding, while « special materials may be divided into « light alloys and high-tensile steels.

« 18. For high-speed trains the stream- « lined form has a large influence on « the consumption of energy.

« The maximum result will be obtain- « ed from the complete streamlining of « the whole train set.

« 19. Roller bearings are used as much « to reduce lubrication and maintenance « costs as to save energy; in consequence « they are found more widely on motor « coaches than on locomotives, and have « been applied to motor armatures more « frequently than to the locomotive or « train axle journals.

« 20. Electric heating of vehicles is « normally adopted on most electrified « systems, the steam heating apparatus « being maintained. Fuel-fired boilers « are used only in the case of vehicles « drawn by both steam and electric lo- « comotives, but they cannot be regarded « as a means of saving energy.

« 21. The fitting of thermostats on « electric heating systems often leads to « considerable energy savings.

« 22. The use of a single electric heater « in conjunction with a system of hot « air ducts in each coach may be more « economical than the fitting of a num- « ber of electric radiators, taking into « account the time required for pre- « heating, the ventilation realised, and « the lightening of the vehicles.

« 23. In winter, the peak load of energy can be reduced by cutting out the heating system when accelerating or ascending heavy gradients or during the periods of heaviest traffic.

« 24. Present systems of regenerative braking are of value only on lines having long heavy gradients, since they operate only above certain speeds.

« 25. Systems on trial on direct-current lines which operate down to low speeds and can be used for normal train stops may prove of considerable value because they reduce the consumption of energy in services with frequent stops.

« 26. In suitable cases, the question of awarding bonuses to train drivers, for economical consumption of energy by the driving motors, might be considered, providing these are combined with awards for punctuality. »

3rd SECTION. — Working

QUESTION VII.

Economical operation of the main line systems' secondary lines. Various methods adopted to adjust the operating facilities, safety measures, and station organisation to the volume of traffic.

Summary.

« 1. The organisation of the different services on secondary lines of main-line systems should have as its aim the reduction of operating expenses to a minimum.

« The fact should not be overlooked, however, that it is essential to improve the service of both passenger and goods traffic as much as possible in order to recover, at least in part, traffic lost to road competition.

« 2. The possibility of reducing the expenses must be sought in the field of technical installations, in the domain of the methods of transport and in the adoption of simplified operating methods.

« 3. Technical installations should be adapted to actual traffic requirements and not require any costly upkeep.

« Simplification of signalling, and even elimitation of signals where possible, simplification of the operation of points and other appliances, discontinuation of guarding at certain level crossings, are all measures frequently adopted, which can be recommended with a view to effecting savings.

« 4. Substitution of more economical methods of transport for ordinary trains is one of the essential conditions for reducing expenses. From this standpoint, the use of light trains or railcars, when traffic conditions, either passenger or goods, are not against it, gives appreciable advantages.

« It is also advisable to restrict the number of classes in passenger coaches by abolishing first class and, where possible, also second class.

« 5. Light trains should be made up with the object of realising economical operation and utilisation. (For example « push and pull » trains driven from either end, and locomotives fitted for one-man operation.)

« 6. Railcars have undergone a very

« rapid development, which is worthy of « being followed up . They have made it « possible considerably to increase the « commercial speeds, to increase the « train frequency and the number of « stops; in fact to greatly improve the « working on secondary lines.

« It is desirable in certain cases that « railcars should be capable of being « coupled together and of pulling one or « more traillers.

« 7. From the point of view of techni- « cal operation the greatest possible sim- « plification of traffic rules is recom- « mended, also the reduction of the num- « ber of stations at which operating mo- « vements take place. To this end some « systems have found it useful to con- « centrate train control duties in select- « ed stations or in dispatching offices.

« It can also be advantageous to leave « station shunting movements to the « crew accompanying the train on secon- « dary lines if this results in a reduction « of the total personnel on the line.

« 8. From the point of view of the « commercial organisation of stations, « the advisibility of adopting simplified « methods of making out the charges, « and of accountancy, should be stressed.

« 9. Simplified methods of operation, « rates application and accountancy « make it easier, wherever possible, to « commit the management of unimpor- « tant stations to private individuals. « Such « caretakers », bound to the rail- « way by a contract, usually perform all « station duties except those relating to « traffic safety.

« 10. Finally, it is advantageous to « convert certain small stations or halts « into unstaffed establishments, tickets « being issued and collected by the train « staff, and the goods being forwarded « or delivered—when such places are « open to goods traffic—as if such pla- « ces were private sidings off the open « line. »

QUESTION VIII.

Application of rational organisation (planning) to the transport of goods.

especially in connection with :

1. **the functions and internal working of shunting yards;**
2. **the provision of inter-yard connections;**
3. **the estimation of the probable traffic to be dealt with, and the provision of the trains required;**
4. **the information to be given to the consignees;**
5. **the acceleration of the turn-round of empty stock;**
6. **the use of containers and rail-road wagons.**

Summary.

I. Organisation of the service in shunting yards.

« 1. In a general way, care should be « taken that the organisation of train « shunting and marshalling work meets « the operating requirements; there is « already great uniformity in the prin- « ciples governing organisation of the « work and the sequence of the opera- « tions.

« 2. The economical working of shun- « ting yards is strongly influenced by the « rational arrangement of timetables. « These should have as their object, on « the one hand, the reduction to a mini- « mum of the time spent by wagons in « the shunting yards (when the wagons « are standing a very short time, better « use is made of them and the number

« of wagons required is smaller) and, on « the other hand, the attainment of a « proper succession of the trains, adapt- « ed to suit the capacity of the shunting « yards, which is also reflected in a bet- « ter use of the shunting gangs and loco- « motives.

« 3. As exact a plan as possible of the « work to be done in the shunting yards « and the way it is to be carried out « should be drawn up, both as regards « time and work. The staff and locomoti- « ves should be allocated in such a way « as to ensure their economical use; a suf- « ficient margin must be allowed for fre- « quent abnormal demands, whereas for « cases of special demands, which rarely « arise, the plan must be departed from. « The plan should provide for suitable « connections between arriving and de- « parting trains.

« 4. The establishment of a working « plan pre-supposes a knowledge of the « time required for the different opera- « tions and the amount of labour needed « to carry them out.

« The carrying out of an existing plan « does not usually lead to any difficulty « in splitting up the trains, as long as « the traffic is sufficiently dense.

« When making up trains, on the con- « trary, the diversity of the trains and « the variable density of the traffic af- « fect the working time so much that « the unit values calculated from the ave- « rage number of trains are, as yet, only « rarely sufficient for planning the « work.

« Thus a regular and uniform rhythm « of shunting operations has, up to the « present, only been realised in excep- « tional cases.

« Consequently a satisfactory planning « of the shunting operations must de- « pend to a large extent on the particular « circumstances of the moment.

« 5. Mechanical equipment, remote- « controlled brakes, and automatic point « operation have given excellent results « in large shunting yards; the operations « are speeded up and the efficiency of « the yards increased.

« On large Railways with heavy traffic, « it is possible to concentrate in large « marshalling yards the work of making « up trains, reducing as much as possi- « ble the work at small yards, and espe- « cially at junction stations.

« 6. The study of the organisation of « marshalling yards has generally been « less developed than that of splitting « up yards. Since the work of making « up trains is that which involves the « greatest expense in machines and loco- « motives, it is desirable that Adminis- « trations should study the most econo- « mical methods of making up trains, « taking into account the preparatory « work which can be done at the time « of splitting up, thanks to a judicious « allotment of tracks.

II. *Train services between marshalling yards.*

« 1. If fast working is to be obtained, « an essential condition is that marshal- « ling yards be interconnected by trains « which are not required to serve inter- « mediate stations.

« 2. If the traffic arrives in sufficient « quantities, it is recommendable to « work it through to distant receiving « stations, avoiding one or more inter- « mediate shunting yards, provided the « time taken to collect the wagons in the « shunting yard before departure is « shorter than the time to be saved on « shunting and marshalling in interme- « diate shunting yards.

« 3. If the quantities of wagons to be

« forwarded are small, so that the time « required to collect a sufficient number « for direct despatch to the most distant « receiving station is too long, by « making up lots of wagons which ar- « rive at the shunting yard and mars- « halling them as they are into a train « made up therein, all the work to be « done can be completed as quickly or « even more quickly if the time to col- « lect them is appreciably shorter.

« 4. There should be enough regular « trains to work the traffic experience « shows may be expected, and to obtain, « by good transfer possibilities, satisfac- « tory through train workings in the « case of long-distance goods traffic.

« 5. The intended running of optional « trains should be made known as « quickly as possible in order to avoid « delays in the conveyance of goods, « avoid interfering with the working of « the stations by blocking them up, and « to make good use of the locomotives « and staff required to work the optional « trains. The timetables for the optional « trains should be prepared at the same « time as those of the regular trains and « be inserted in the working timetables.

« 6. It is recommended that the orga- « nisation of the running of special « trains, on large Systems with dense « traffic, should not be left to the sta- « tions but should be entrusted to a dis- « trict office (traffic control, dispat- « cher) having wider jurisdiction.

III. *Estimation of the traffic to be dealt with and of the trains required.*

« 1. As regards the probable general « trend of the traffic and the important « individual loads, it is only possible to « form an opinion some time beforehand « by keeping in close contact with the « consignors, by taking into account pre- « vious experience, by railway and eco- « nomic statistics and — a relatively short « time ahead — by the demands for « empty stock; there is no standard me- « thod of solving these problems.

« 2. In the case of consignments al- « ready handed in for despatch, there are « preliminary advice methods, either « between despatching and receiving sta- « tions and marshalling yards, or through « the medium of central offices which « notify the information received from « the departure stations to the other sta- « tions concerned and, in some cases, to « neighbouring Railways.

IV. *Advice to be given to the consignees and consignors.*

« 1. Nearly everywhere the consignee « is advised of the arrival of his goods « and of the fact they are ready for off- « loading, so that the wagons, sidings, « and loading platforms can be made « available again as quickly as possible.

« 2. In advising the consignee, no ac- « count is taken of the fact that, accor- « ding to general practice, he is inform- « ed by the consignor of the day and « hour of departure and consequently « can calculate the probable day and « hour of arrival, from his own expe- « rience or with the help of a goods train « timetable or similar documents.

« Because of the active competition of « the road motor car, it seems important « for Railway Administrations to exa- « mine the possibility of advising the « consignor as soon as possible of the « probable date of arrival of the goods.

« 3. When the demands for wagons « are heavy, the advice notice — together « with the intimation that the period

« within which the goods are to be unloaded is shortened — if need be — is particularly important; the preliminary advice, by the last station of call to the receiving station, of the probable time of arrival of goods of some importance, is to be recommended.

V. *Acceleration of the turn-round of empty stock.*

« The turn-round of empty stock is accelerated by the following methods, the application of which depends on the particular conditions of the Railway concerned and the kind of traffic worked :

« *(a)* Concentration of the empty wagons at large collecting centres from which they can be distributed to the consuming points;

« *(b)* Working empty stock towards the regions generally short of wagons, without special demands having to be made;

« *(c)* Working the wagons in special empty-stock trains, which do not shunt in the marshalling yards and avoid all unnecessary stops. These very light trains are formed with the maximum number of axles and their timings adapted to the small weight hauled;

« *(d)* At times of great demand for rolling stock, in order to reduce the turn-round time of the wagons, authority to reduce the load of trains below the nominal value, increased service of loading points, extension of working hours at stations and the preliminary notification to customers of the time that empty wagons will be at their disposal.

V. *Use of containers and road-rail wagons.*

« 1. Only some Railways, especially those with their own collection and delivery services, have left the experimental stage as regards the use of containers. It appears that the questions of the rates and conveyance between the railways and the consignor's or consignee's premises can be solved satisfactorily.

« 2. It is specially important in the case of large container traffic, to suitably arrange the transfer from road to rail vehicles and inversely. Especially useful for this purpose are mobile cranes, which run on the road alongside the railway wagons and economise on all shunting operations. Difficulties in the use of large containers can mostly be traced to the lack of such mobile cranes or other powerful unloading equipment, at stations and on the premises of consignors and consignees.

« 3. Small containers used for parcels and special small consignments appear to be advantageous, especially from the point of view of the reduction of transhipment operations, and to facilitate handling.

« 4. Undoubtedly, the use of containers for door to door transport has an extremely favourable influence on the ability of the railway to meet competition.

« 5. Road transport of railway wagons is only at present in use on a few Railways. The use, by some Railways, of special road vehicles for carrying railway wagons has given satisfactory results. Nevertheless, the time

has not yet come for formulating a definite judgment.

« One can also consider, in order to ensure « door to door » transport, the use of lorries or trailers loaded on to railway wagons at the nearest station to the sending establishment and unloaded similarly at the nearest station to the receiving establishment. »

QUESTION IX.

Results obtained from the automatic and distant operation of signals and points, and from locomotive cab signals.

Summary.

Automatic block.

« 1. The automatic block, on heavily loaded lines, is an excellent means of providing adequate headway between trains running in the same direction, as regards both safety and the capacity of the line.

« 2. The block signal at « danger » should generally necessitate the train being brought to a standstill.

« Nevertheless, in certain exceptional and justified cases, steps can be taken to avoid enforcing a stop on certain heavy trains at some block signals at danger, on very heavy rising gradients.

« 3. After stopping (or exceptionnally without stopping as mentioned above) the « danger » indication of the block signal should mean that the driver is to proceed with caution. There appears to be no objection to the train restarting immediately without further ado, as is done on many Railways.

« 4. A driver proceeding with caution when he has met a block signal at « danger » should run « at sight », « i. e. at such a speed that at any mo« ment he can stop on the length of line « in sight.

« Some Railways have found it advan« tageous to require the driver in addi« tion to running at sight, not to exceed « a given speed.

« 5. In short sections at least (not ex« ceeding 3 km. = 1.9 miles) a good « method of protecting trains stopped on « the open road is to rely on the block « and not to require the staff on these « trains to resort to additional protec« tive measures (except in certain parti« cular cases laid down by the railway « regulations).

« 6. In the case of the automatic block « with mechanical signals, some Rail« ways consider it prudent to provide « a « continuity » device which main« tains a block signal at « danger » after « the corresponding section has been « cleared, in the exceptional case in « which the following block signal has « not gone to « danger » after a train « has passed.

« This measure gives certain guarantees « but has some drawbacks. The best so« lution appears, therefore, to use light « signals instead of mechanical signals « whenever possible.

« 7. Whatever type of signal be used, « even in the case of light signals, some « Railways deem it necessary to take pre« cautions (double relays, or continuity « devices) against the exceptional case « of a block relay not becoming de-ener« gised when a train has passed, whereas « other Railways, chiefly to reduce the « number of times the block signals un« duly go to « danger », take no such « additional precautions.

« The essential thing is to use excel« lent relays only.

« 8. The coded block, although in use « only a short time, appears to be a « particularly safe form of automatic « block.

« 9. Conditions under which light ve- « hicles as well as vehicles with pneu- « matic tyres can be allowed to run over « automatic block sections with safety « still require investigation.

Power boxes.

« 10. Power boxes with route levers, « in which one lever operates the whole « of the points and signals on a route, « appear to specially facilitate the work- « ing, provided they contain apparatus « which lends itself to all kinds of train « movements.

« 11. At the present time there is a « tendency to use very small (miniature) « levers and replace the interlocking pro- « perly speaking i. e. locking the levers « into position, by directly cutting the « operating circuit of the apparatus in « question by means of a relay.

« 12. Power boxes lend themselves « particularly well to providing all the « safety conditions that can be desired. « It is to be recommended that provi- « sion be made in these boxes for sec- « tion locking, point locking, route « locking, and approach locking.

« 13. Issuing instructions covering the « failures of electric devices preventing « point or signal movements in a power « box is a delicate question. The trains « affected should not be allowed to pass « at speed the whole time the device is « out of order. It is recommended, more- « over, that any electric interlocking out « of order should be cancelled by the « signalmen and « repeater » devices « used each time the defective equipment « is operated.

« 14. Long-distance point operation, « by means of devices with few control « circuits and operating circuits, gives « excellent results and appears likely to « be developed considerably, in particu- « lar for operating single-track lines « with heavy traffic, as it may make it « unnecessary to double such lines.

« 15. Automatic point operation by the « trains themselves also gives good re- « sults, at least with simple track layouts.

Locomotive cab signalling.

« 16. It is desirable to facilitate the « work of the driver by equipping the « engines with signal repeating devices « or with continuous signalling; automa- « tic braking can be added with either « arrangement.

« This cab equipment is mainly re- « quired on busy lines or lines run over « by high-speed trains.

« 17. Steps should be taken to pre- « vent the driver becoming less vigilant « when such equipment is provided.

Signal repetition.

« 18. Distant signals (warning and « speed restriction) should be repeated « and registered on the locomotive. It is « also useful, in order regularly to verify « that the apparatus is in working order « to repeat and register these signals « when off.

« 19. Cab signalling equipment with « purely mechanical transmission of the « indications is only suitable for trains « running at low speeds.

« 20. Equipment with electro-mecha- « nical (contact) transmission should « preferably give the « danger » indica- « tion by cutting off the current.

« 21. Non-contact devices are definitely better than those working by contact.

Continuous signalling on the locomotive.

« 22. It is desirable as a rule to retain the fixed (way-side) signals, even when cab signals are fitted on all the locomotives running on the line.

« 23. There does not appear to be any disadvantage in giving one more indication on the engines than those given by the fixed (way-side) signals (advance warning, for example). This is particularly valuable in the case of a section of line run over by some ultra-fast trains for which the permanent-way signalling has become inadequate.

Comparison.

« 24. From the working point of view, and also to some extent from that of safety, continuous signalling is better than signal repeating, even with non-contact apparatus.

« 25. Continuous signalling is much more costly than signal repeating, even in the case of non-contact apparatus, when the line is not already equipped with the automatic block. This system, therefore, can only be considered by railways already equipped or to be equipped with the automatic block on a large scale.

« The Railways which for some reason or other are not proposing to install the automatic block on a large scale are rather led to adopt signal repetition, preferably by means of non-contact equipment.

Automatic braking.

« 26. Automatic braking limited to home signals passed at « danger » raises no difficulty in principle, but is only suitable for lines that are not run over by high-speed trains.

« 27. On lines run over at high speeds, the brakes should be applied automatically at the distant signal. The application of the brakes can be independent of the train speeds or depend thereon.

« 28. Automatic braking independent of the train speed involves the provision of means by which the driver can cut out the automatic action when he has sighted the signal. Consequently this braking is especially superior to signal repetition alone and continuous cab signalling alone, in the event of the total incapacity of the engine crew.

« 29. Automatic braking depending on the train speed is more valuable than the former, especially in the case of ultra-high speed trains; it is incontestably of lower value when the engines are equipped with cab signals. »

4th SECTION. — General.

QUESTION X.

Effects of the world crisis and road competition on the railway position. Corresponding changes in railway commercial policy.

Summary.

« 1. Under the influence of trade recovery throughout the world, rail-borne traffics generally show a certain increase which, however, falls short of the general increase in production.

« One of the primary causes why the financial situation of railways is slow in improving in most countries is the fact that exchange of goods between different countries is handicapped by import restrictions, systems of « clearing, control of currency, and monetary instability.

« It is therefore desirable, in the interests of the financial equilibrium of transport undertakings, that artificial barriers limiting international commerce should be lowered, and in so far as possible, suppressed.

« 2. But the most important cause of the delay shown in the improvement of the financial situation of Railways lies in the continual development of road transport competition.

« In fact, in every country, the number of motor vehicles and their loading capacity are increasing, at the same time as roads are being extended and improved. The consequence is that competition from road vehicles becomes more and more acute, and the harmful results of this are reflected in the general position of Railways.

« Although road transport must have a place in the field of transport, the question of its rightful place in that field cannot yet be said to have been answered with any degree of finality.

« 3. Railways are under legal obligation to ensure public transport in accordance with principles dictated by general public interests. The consequence to Railways is that they have special responsibilities not incumbent on other methods of transport which, not being bound by the same obligations to public interest, are free to pick and choose their traffics, and fix their tariffs.

« Under rational organization, road transport should be complementary to, rather than competitive with, rail transport. It should, therefore, only be encouraged to the extent to which it is essential and affords a type of service not possible by rail. It is desirable, in particular, that special care should be taken to conserve long-distance and heavy traffics to the Railways, whose economic status should, in the general interests, be preserved.

« 4. It is desirable that the closest possible co-ordination should be brought about between Railways and road motor vehicles offering a service to the public, notably by the following means:

« (*a*) By participation of Railways in road transport, a participation which may, in certain cases, extend as far as concentration under one management;

« (*b*) By an allocation of traffics between the two methods of transport

« either by mutual agreement sanc-
« tioned by the Authorities, or by direct
« orders from the Authorities.

« (*c*) By substituting, for competitive
« road services, combined road-rail ser-
« vices such as containers, transport by
« rail of loaded lorries or trailers, etc.

« In order that efforts to coordinate
« public transport may not be nullified,
« it is also necessary that appropriate
« measures be taken to regulate private
« transport of goods by road motor, par-
« ticularly over long distances.

« The application of these various
« measures would require the existence
« of sufficient motor traffic statistics,
« such as are already drawn up in some
« countries.

« 5. With the object of avoiding un-
« fair competition, and to give to the
« patrons of road hauliers the necessary
« security (as also to other road users),
« the appropriate Authorities should :

« (*a*) Keep under strict observation all
« road vehicles and see that the trans-
« port bye-laws are carried out, through
« the intermediary of the local police,
« with the main object of securing great-
« er safety on the road;

« (*b*) Insist on all public road ve-
« hicles carrying out their responsibili-
« ties towards their clients, covering
« themselves against third-party risks in
« the same way the railways are obliged
« to do;

« (*c*) Adopt conditions of service in
« respect of staff employed in the pu-
« blic transport of both passengers and
« goods, comparable with those in force
« on the railways of the country.

« 6. In order to suit all economic
« needs, it is important that all methods
« of public transport adopt published
« tariffs, consistently applied, and based
« as far as possible on the same prin-
« ciples. If, in other respects, conditions
« of equality could be achieved between
« rail and road transport, the carrying
« out of such a measure would avoid the
« unnecessary reduction of their existing
« rates by both parties.

« Until such time as this rather diffi-
« cult question has been solved, the Rail-
« ways of most countries are compelled
« to resort to the lowering of rates.

« The reduction of rates in specific
« cases, sometimes granted only on con-
« dition that the firms concerned hand
« over the whole of their transport to
« the Railway, has been found to give
« better results than general rates re-
« duction.

« 7. On those services where working
« is to be continued by the railway, the
« improvement of passenger facilities, by
« increasing the speed and frequency of
« trains, as well as improvements in their
« comfort, have proved to be efficacious
« means of meeting competition, and it
« is desirable to continue in this di-
« rection.

« On the goods side, experience has
« shown that regularity in delivery times,
« acceleration of transport, and extension
« of door-to-door facilities, are excellent
« means of increasing traffic, and should
« be adopted wherever desirable.

« 8. The experience gained by the dif-
« ferent Railway Administrations has
« shown the benefits obtained from suit-
« able advertising and general propa-
« ganda. It is most desirable that all
« forms of advertising and propaganda
« be developed, that canvassing for traf-
« fic be intensified, that closer contact
« with clients be obtained in order bet-
« ter to understand their wishes and
« needs, and keep them informed as to
« the various possibilities and advantages

« to be derived from the use of the rail-
« way.

« 9. Speaking more generally, Rail-
« ways must continue to follow the com-
« mercial methods which have been prov-
« ed sound in other spheres of bussiness,
« especially since they now no longer
« enjoy a virtual monopoly of transport.

« Wherever necessary, it is desirable
« that Government Authorities should
« afford the Railways the necessary fa-
« cilities to carry out a policy of a com-
« mercial character.

« It is also particularly desirable that
« Railways introduce methods designed
« to encourage the interest of employees
« in the development of traffic and the
« economic position of the railway ser-
« vice. »

QUESTION XI.

Selection, orientation and instruction of railway staff.

Summary.

« I. As regards the selection of staff,
« the reporters found that :

« 1. Psychotechnics are being applied
« gradually by many (18) Railway Ad-
« ministrations who consider this me-
« thod as an indispensable factor of a
« rational selection of their staff.

« 2. Psychotechnics tend to increase
« the quality and quantity of the staff's
« output and to reduce the number of
« accidents due to the human element.

« 3. The coefficient of concordance of
« the professional value of railway staff
« in actual service as compared with the
« results of the psychotechnical exami-
« nations, is between 70 and 90 %.

« 4. Psychotechnical methods applied
« to the professional training of staff
« promises to make it more rapid, effi-
« cient and less costly.

« 5. The psychotechnical methods
« adopted by the different Administra-
« tions are not uniform; some tests are
« used which differ more or less in kind
« and number.

« In view of the results of the exami-
« nation of the question, it was thought
« advisable to recommend to all the Rail-
« way Administrations :

« 1. To introduce psychotechnical me-
« thods for the selection of their em-
« ployees and to contribute to the deve-
« lopment of these methods.

« 2. To standardize methods of psy-
« chotechnical tests applied to candida-
« tes to the railway service, especially to
« certain functions dealing with working
« safety (signalmen and pointsmen, en-
« gine drivers and drivers of railcars)
« and to favour in the best possible
« manner the exchange of views and ex-
« perience acquired in this connection.

« 3. To take into consideration the
« usefulness of periodical examinations
« for certain functions in connection
« with the safety of the working.

« 4. To introduce into their statistics
« of accidents a more precise qualifica-
« tion of causes due to the human ele-
« ment, conjointly with the result of the
« psychotechnical examinations of the
« members of the personnel involved in
« these accidents.

« II. The professional guidance of
« staff is not applied according to the
« results of the psychotechnical exami-
« nations owing to the fact that these
« examinations are exclusively applied
« to candidates for given duties.

« Seeing that the professional gui-

« dance of the staff according to psy-
« chotechnical methods, seems to be of
« special interest, the Meeting proposes
« that this matter be placed on the agen-
« da of the 14th Session of the Interna-
« tional Railway Congress Association.

« III. Methodical education of candi-
« dates for the various departments as
« well as the improvement of staff al-
« ready in service usually take the form
« of schools and special lectures.

« It must be recognized that such edu-
« cation is given in rather various ways.

« The introduction of psychotechnics
« during the course of such instruction
« takes place only on the German State
« Railways, and it seems advisable for
« all the other Railway Administrations
« to adopt the same methods.

« The Meeting expresses the desire
« that, together with the transformation
« of installations and ways and means
« of operation, already in progress, the
« various Administrations consider the
« necessity of adapting to the new state
« of affairs the education of staff al-
« ready in service, by means of specially
« organised training courses. »

5th SECTION. — Light railways and Colonial railways.

QUESTION XII.

Co-ordination of operation as between main-line and light railways.

Summary.

« 1. In all countries, co-ordination of operation of the main-line and secondary railways is recognised, in principle, as not only useful, but necessary in the general interest.

« 2. It is generally considered as an effective means of meeting the growing competition of other more modern methods of transport.

« With particular regard to the *installations :*

« 3. In the case of two railways of the same gauge, it is preferable to have common junction stations in which the existing equipment of the main-line railway is used to cover the needs of the secondary railway.

« 4. In the case of railways of different gauges, with separate stations near one another, the narrow-gauge line
« should run into the main-line rail-
« way station, unless transporter trucks
« are used; in this case it is desirable
« that the connection should be a stan-
« dard-gauge line.

« As regards *operation :*

« 5. Both in joint stations and in se-
« parate stations connected together, the
« main-line railway should co-operate
« with the light railway to the maximum
« possible extent, in return for suitable
« compensation.

« 6. Through (interchange) traffic
« should be dealt with under a combined-
« service system, with a single transport
« contract (waybill) and joint responsi-
« bility of the carriers.

« 7. When a combined service is im-
« possible or inconvenient, the carriers
« should make agreements about corres-
« pondence services for carrying goods
« without intervention of the parties
« concerned at the junctions, fixing ac-
« cording to the best interest of the users
« the limits of responsibility and com-

« petency of each carrier, administrative-
« ly and legally.

« 8. It is desirable that the carriers
« should control their own rates, and
« on the basis of these rates each carrier
« should receive the remuneration due
« for the services actually carried out
« on his line.

« 9. It is always better for through
« transport to follow the cheapest route
« unless this seriously interferes with
« prompt delivery.

« 10. It is not desirable, in principle,
« to enforce transit in the case of
« through traffic, even when the transit
« route is the shortest.

« 11. When common stock and the
« indiscriminate use of goods wagons
« are not considered advantageous, rail-
« ways of the same gauge, provided sa-
« fety is not affected, should make agree-
« ments for the reciprocal exchange of
« goods wagons, or at least for running
« main-line vehicles over the secondary
« railway.

« 12. In the case of narrow-gauge rail-
« ways, carriage on transporter trucks
« or in containers may very effectively
« prove an adequate corrective of the
« difference in gauge.

« 13. In the case of passenger services,
« connecting the light railway with im-
« portant centres on the main-line rail-
« way, by means of trains continuing
« over sections of the main-line, can be
« tried with profit.

« 14. As regards *competition*, conjoint-
« ly with the more important means in-
« vestigated by the technical services to
« get the best out of co-ordination, the
« following can be recommended :

« (*a*) The main-line railway should
« co-operate to the maximum extent in
« increasing the average speed of goods
« in through traffic;

« (*b*) The greatest possible extension
« of « door to door » transport, even at
« all stations of both the main-line and
« secondary railways, and, where re-
« quired, the organisation of road trans-
« port in districts not served by rail;

« (*c*) Whilst safeguarding the auto-
« nomous organisation of each railway,
« the accountancy work should be sim-
« plified as far as possible and the par-
« ticular branches of the services should
« be combined in order to eliminate du-
« plication. »

QUESTION XIII.

Specifications for the fixed plant of railway with light traffic, intended to prevent the use of unnecessarily expensive track equipment, and generally to give economical working.

Summary.

« 1. In most countries the general ten
« dency is no longer to construct rail
« ways for light traffic.

« 2. Whenever special circumstances
« however, necessitate the constructio
« of such railways, it is recommended t
« build them to the same gauge as thos
« lines to which they are to be joined
« or to the same gauge as that of th
« railway which they are to complet
« and to adopt conditions of lay-out an
« gradient section which would allow o
« the reduction of traction costs.

« 3. As far as the railways at preser
« in operation are concerned, it is n
« cessary :

« (*a*) To concentrate as much as possible the fixed installations of the stations (buildings, points and crossings) taking into account the requirements of the traffic, in order to reduce to a strict minimum the maintenance costs, train manœuvring times and the necessary staff for the operation of the stations.

« (*b*) To take full advantage of experience and technical progress as far as is compatible with the operation of such lines, in order to reduce as much « as possible the necessity for specialised « staff.

« (*c*) To profit from the renewal of « installations subject to wear and tear « by the employment of more appropriate « installations, brought about by acquir- « ed experience, and modern processes « (use of heavier rails, welding of rails, « transition curves, etc.) or to complete « the equipment of the lines by certain « installations which, in accordance with « the progress of technical science, also « offer better conditions to reach the « proposed end. »